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DIPLOMA THESIS:

Analytical Study and Investigation of Bishop Iosif's Androusis Mitre

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Abstract

The present thesis investigates the Mitre of the Bishop Iosif Androusis (1770-1844). The Mitre is an elaborate bejewelled ceremonial head covering, worn only by bishops. The Mitre under study has a spherical shape and is composed of silk and cotton fabrics soaked in animal glue. It is decorated with metallic embroidery made of gilt silver (Ag), wound around a silk core, and three types of metallic sequins, some of which are coloured red. The metallic sequins are made of silver and silver-copper alloy. Different analytical methods were used, such as Optical Microscopy (OM), Scanning Electron Microscopy coupled with Energy Dispersive X-ray spectrometry (SEM/EDS), and Fourier transform infrared spectroscopy (FTIR), as the most suitable methods for the analysis of the materials of the Mitre. After the thorough investigation and identification of these materials and the documentation of the degradation signs the Mitre presents, a conservation plan was conducted including also suggestion about the most appropriate storage conditions for the Mitre.

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I want also to express my very profound gratitude to my parents, Georgia and Giannis and to my brother Christos, for funding and provide me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. At this point, I can not overlook and thank Ektoraki for his unlimited patience all this time.

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Author

Maria Koutsodimitropoulou

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*** The pictures of the objects are from the archive of Ephorate of Antiquities of Messinia**
**** The source of the figures are cited in footnotes**

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Introduction

The present thesis investigates the Mitre of the Bishop Iosif Androusis (1770-1844). The Mitre is a characteristic liturgical vestment that bishops wear and, more specifically, it is an elaborate ceremonial head covering. They are composite objects, made of various materials, e.g., fabrics, metals and paper. The Mitre under study dates to the 19th century and represents a unique and uncommon type of Mitre in Greek orthodox tradition (Athanasios Tsalagas, p.c.).

The main aim of the thesis is to identify and record the morphological and technological characteristics of the Mitre. More precisely, to investigate the component materials and the manufacturing techniques used for its making. To that end, different analytical methods will be used, such as optical microscopy (OM), Scanning Electron Microscopy coupled with Energy Dispersive X-ray spectrometry (SEM/EDS), and Fourier transform infrared spectroscopy (FTIR), suitable for the analysis of the materials of the Mitre. The secondary aim of the thesis is to study the deteriorated parts of the Mitre and based on the examination of the results obtained from the analysis to make suggestions about the most appropriate conservation treatment.

The structure of the thesis is as follows: Chapter 1 provides the historical information about Bishop Iosif Androusis, owner of the Mitre, and a short presentation of the various liturgical vestments, including Mitres. Chapter 2 reports on the detailed documentation of the Mitre and its case, and of their current state of preservation. It also presents the samples taken from the materials, which will be investigated. Chapter 3 gives general information about the main materials analysed in the current study. In chapter 4, the various analytical techniques which will be applied in the analyses as well as the equipment used are presented. Moreover, it discusses the results that our analyses yielded with respect to the identification of the fabric samples, of the samples taken from the metallic decoration, as well as those of the adhesives and of the paper present on the Mitre. In chapter 5, the proposal about the most appropriate conservation treatments is given, based on the chapters 2 and 4. Chapter 6, summarises the results of the study and the recommended conservation treatment, and concludes with a proposal for future investigation.

CHAPTER 1
Brief historical background

In this chapter, a brief historical reference will be made regarding the objects that are under investigation in the present study. First, the biography of the owner of the Mitre, Iosif Androusis (1770-1844), is presented, who was a prominent personality in his time. Subsequently, a brief introduction to the liturgical vestments and how they are classified according to the degree of the priesthood will be given. Finally, the Mitre as an exceptional liturgical vestment, which is the main object of this study will be discussed. Its meaning, symbolism and the manufacturing technology, as it is formed during the centuries, are the main points that the current chapter will be dealing with. These pieces of information compose a precursor for the following chapters.

1.1 Biography of Iosif Androusis

The Bishop of Messini, Iosif Androusis (1770- 1844) (see *Figure 1.1*) was a great personality of the period prior, during and after of the Greek War of Independence (1821) (Bougas 2009: 6, Themelis 2003: 40). He served the Greek nation for approximately 50 years with his national, religious and spiritual actions (Bougas 2009: 7, http://mmess.gr).

Iosif was born in 1770 in Tripoli (Arcadia, Greece), and at the age of 20 he decided to become a monk (Bougas 2009: 9-10, Themelis 2003: 39 and 45-46). Not long after that he ordained deacon (1792) in Tripoli, where he remained for 14 years, serving with sincerity and devotion his benefice (Bougas 2009: 11). His experience made him able to undertake the diocese of Androusa after the resignation of Bishop Constantine because he was very old. On April 27, 1806, at the age of 36 years, Iosif was ordained bishop of Androusa and remained in this position until the abolition of the diocese in 1833 (Themelis 2003: 39 &45-46). The diocese of Androusa included most of the

Messenia's provinces and was based in the city of Androusa, where the bishopric was (see *Figure 1.3* and *1.4*) (Bougas 2009: 15).

Figure 1.1: Bishop Iosif Androusis (Chrisostomos 1961: 2)

Figure 1.2: The marble bust of Iosif Androusis in the courtyard of the Church of St. John in Messini[1]

His virtuous life, modesty and humility, combined with his gifts and abilities, had made Iosif, well known throughout Peloponnese. The Turks quickly were informed about his actions and sought his physical extermination. During the siege of Tripoli (Easter Sunday 1821), he was arrested and kept as hostage, and was subjected to horrible tortures (Bougas 2016, Bougas 2009: 18).

Figure 1.3: Map of the Peloponnese[2]

Figure 1.4: Map of Messenia[3]

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[1] http://beneas13.blogspot.gr/2013/01/blog-post_7.html
[2] http://www.greece-map.net/maps/peloponnese-map.gif
[3] http://www.united-hellas.com/tourism/pelop/images/map-messinia.gif

The First National Assembly of Epidaurus on January 15, 1822 entrusted Iosif the Ministry of Religious, which was one of the eight new Ministries established (Bougas 2009: 21, Bougas 2016). He was the first Bishop, after the liberation of Greece, who exercised simultaneously religious and political tasks. On November 21 1833, by a Royal Charter, Iosif became Bishop of Messini, based in Messini (or Nisi), where he remained until his death in 1844, making him the last Bishop of Messini (Bougas 2009: 12,Themelis 2003: 29). In 1852, the diocese was named Messenia (Bougas 2009: 53, Themelis 2003: 29).

On March 13 1844, Iosif died, being at the age of 74 (http://mmess.gr, Tserpes 1998: 68). He was buried in front of the Great Gate of the Church of St. John in Messini. His marble bust, created by a local sculptor Mr. Tomporou was placed at the church's yard (see *Figure 1.2*) (Tserpes 1998: 68). Iosif Androusis had arguably a forceful personality, which affected people and events of his time as well as of later years. Admittedly, his contribution was essential and priceless to the history of Messini (Bougas 2009: 7).

1.2 A short overview of the liturgical vestments

The liturgical vestments are garments used by Orthodox Christian clergy during the Divine Liturgy as well as in other church services and indicate the transition from the secular to the sacred (Chrisostomos n.d., Dardamani 2009:78). There is a particular sartorial ensemble that corresponds to each of the three degrees of the clergy, the bishop, the presbyter and the deacon. The vestments are seven and are distributed according to the three degrees of the priesthood. Each level includes the vestments of the lower grade with the addition of some extra pieces (see *Table 1.1*) (Vlachopoulou-Karabina n.d.).

Table 1.1: The Liturgical Vestments for each of the three degrees of the clergy

Deacon	Sticharion, Orarion, Epimanika
Presbyter	Sticharion, Epitrachelion, Epimanika, Zone, *Phelonion*
Bishop	Sticharion, Epitrachelion, Epimanika, Zone, *Phelonion,* Omophorion, Epigonation, Mitre, Sakkos, Mantle

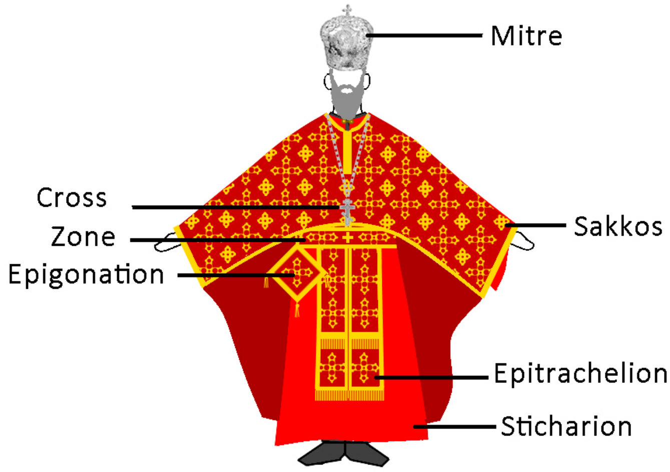


Figure 1.5: Bishop's vestments[4]

The main object of this study is the Episcopal Mitre of Iosif Androusis, for this reason, the following section refers to the meaning, the history and the construction of this exceptional liturgical vestment.

1.2.1 The Mitre

The Mitre is an elaborate bejewelled ceremonial head covering, worn only by bishops as mentioned above. The word itself is derived from the Greek *μίτρα (mitra)*, meaning a 'headband' or 'turban'. Its shape is generally cylindrical with a spherical upper end and it comprises of a number of materials. It originates in the Old Testament and symbolizes the thorn Crown placed on the head of Jesus Christ during his crucifixion, an indication that the bishop suffers and is crucified for his flock and the Truth (Dardamani 2009: 89). Furthermore, it resembles the crown worn by the Byzantine Emperors, as this was shaped at the end of the 11th century. It was adopted by Bishop to emphasize that the head of the Church is God's representative on earth, as the Emperor was before the fall of the Byzantine Empire (Salonidou 2012).

Historically, the Mitre has very ancient roots and can be traced back to Middle Eastern and Greek traditions, since head-coverings were a mark of position of certain religious and secular officials. Its final form, as it is known nowadays, is considered to be an innovation of the later years (Zographou-Korre 1985: 58). From literature and wall

[4] Modified picture
https://upload.wikimedia.org/wikipedia/commons/5/5e/Orthodox_Priest_Liturgy.png
(Mitre) http://etc.usf.edu/clipart/77500/77562/77562_greek_mitre.htm

paintings, it is known that initially clerics had their heads uncovered (Kalokiris n.d). Mitre first appeared in the Early Christian period, and it was only the Pope of Rome and of Alexandria who had the privilege to wear it (Zographou-Korre 1985: 58, Theochari 1986: 19). Later, in the Byzantine and post-Byzantine times, it was worn only by some clergy that probably had the "patriarchal permission". Finally, the use of Mitre by bishops in general has been established during the 17th century (Zographou-Korre 1985: 58).

Figure 1.6: (left) St Cyril of Alexandria[5]
Figure 1.7: (right) Early type of Mitre (mid 15th century). Museum of the Serbian Orthodox Church, Belgrade (Woodfin 2004: 304)

The early type of Mitre comes from the head bandanas of monks, which was a soft circular cap with a flattened top. This kind of Mitre was usually made of precious fabric with gold-embroidery and pearly emblazonments (Zographou-Korre 1985: 59). A characteristic example is depicted in figure 1.6, a wall painting of St. Cyril of Alexandria wearing that kind of Mitre. In addition, two masterpieces of the early type of Mitre are presented in figure 1.7, 1.8 and 1.9, which date from 15th to 18th century.

[5] http://modeoflife.org/the-liturgical-vestments-of-orthodox-clergy/


Figure 1.8: (left) Early type of Mitre (1682). Monastery of Saint John the Theologian, Patmos (Theochari 1986: 37)
Figure 1.9: (right) Early type of Mitre (17^{th}- 18^{th} century) with golden embroideries. The Byzantine and Christian Museum[6]


Figure 1.10: (left) Metallic Mitre (1757). The Byzantine and Christian Museum[7].
Figure 1.11: (right) Mitre of Bishop Chrysostomos of Smyrna (20^{th} century). National Historical Museum, Athens[8]

The type that is generally adopted as an Episcopal Mitre is modelled based on the crowns of Palaiologan Emperors as well as on the head covers of the Byzantine rulers with only small differences. This kind of Mitre has a hemispherical shape and consists of a circular base and two intersecting bands at the top of which a cross is placed, either standing upright or placed flat. The first type was usually made either of metal (see *Figure 1.10*) or of expensive fabrics, usually in red colour, and the second type was made only of fabric with embroidered and pearl decorations (see *Figure 1.11*) (Zographou-Korre 1985: 58).

[6] http://www.byzantinemuseum.gr/el/search/?bxm=1701
[7] http://www.byzantinemuseum.gr/el/search/?bxm=2134
[8] http://panagiotisandriopoulos.blogspot.gr/2014/09/blog-post_7.html

The Mitres are typically made of papier-mâché covering a mould of a spherical shape and then the paper layer is covered with layers of fabric soaked in glue, embroidered by hand and decorated with various materials (gemstones, sequins, metal threads etc.) (Varvounis and Macha-Mpizoumi 2014). The embroidered decoration depicts usually scenes from the life of Christ as well as floral themes (Theochari 1986:19, Zographou-Korre 1985: 59). Often, the crowned headed eagle appears on the decoration, which became a patriarchal emblem after the fall of Constantinople (Theochari 1986:19). Normally, it is inlayed with four icons attached on the sides. These four circular jewels depict usually Evangelists or Jesus Christ, the Theotokos, John the Baptist, and the Cross (Theochari 1986: 19, Zographou-Korre 1985: 58-59).

CHAPTER 2
Objects and Samples

In this chapter, a detailed documentation of the objects under study will be made, namely, of the Mitre and its case; additionally, the construction materials and their current state of preservation and the storage conditions will be presented and discussed. Finally the samples obtained will be presented. The sampling permission granted by the Ministry of Culture included only samples from the Mitre, and that's the reason why the case was not studied further.

The main aim of Chapter 2 is to obtain a better understanding of the objects and of the factors that caused their deterioration. This step is necessary before the further investigation of the objects with analytical techniques. To this end, the first thing to do was the photographic documentation of each object and of the component parts as well as details that exhibit interesting characteristics or/and sign of deterioration. Next, a macroscopic analyses of the objects was conducted, using unaided eye but in some cases the use of a stereoscope and an usb-microscope were used in order to perform a detailed documentation of the object, which is an essential part of any conservation treatment as well as a useful and important source of information for future reference (Karidis 2006: 11, Lennard and Ewer 2010, McLean and Schmalz 2010).

The structure of Chapter 2 is as follows: first, the background information of the objects is presented followed by the description of the Mitre and the case. Then the condition of the two objects is given as well as the previous conservation treatments they have undergone, to end with their current storage condition at the Ephorate of Antiquities of Messinia.

2.1 Background information

The Mitre and the case under investigation belong to the collection of the former Benakeion Archaeological Museum of Kalamata and became part of the collection of the Ephorate of Antiquities of Messinia in 2006. The precise dating of the objects remains unknown, but most likely they were made during the period when Iosif Androusis was the bishop of Androusa or Messini, that is, between 1806 and 1844. The origin of the objects is also unknown. The Mitre, as Mr. Athanasios Tsalagas[9, 10] (p.c.) points out, is rather unique, as it does not exhibit a prototypical, ordinary structure, and this specific type is not very common in Greece. Evidence for its origin comes from its shape and from the roundels with metallic embroidery. Those resemble Ottoman roundels, suggesting that the Mitre might have been constructed in Constantinople as it is perfectly depicted in mosaic of the Chora monastery (see Figure 2.1) or might come from Russia.

Figure 2.1: Detail from a mosaic of the Chora monastery (1315-20), Constantinople[11]

[9] Athanasios Tsalangas- Mitre constuctor
[10] Special thanks for his valuable help
[11] http://www.ime.gr/chronos/10/en/titles/pl/pn/pnd2c.html

2.2 Mitre Description

Figure 2.2: An overview of the Mitre of Iosif Androusis

The Mitre has a cylindrical shape, which resembles a dome. Figure 2.2 shows an overview of the Mitre (see *Figure 1* in Appendix I for more pictures of various aspects of the Mitre). The Mitre has the following dimensions: height 19 cm, circumference of lower part 60 cm, circumference of the upper part 70 cm and thickness 2-2.5 cm.

The object is separated into four parts based on its different layers to ease its description: a) outer layer, b) intermediate layer, c) inner layer; and d) decoration. This division will be also used in the following chapters.

a) Outer layer

The Mitre has (possibly) been made of brown fabric embellished with embroidered bands and metal decorations. It has a metal ornament on the top, where a cross and most possibly, gemstones were placed, which has been removed or detached. The presence of the cross and gemstones is evident by the existence of the holes on it (see *Figure 2.3* and *2.4*). Under the ornament, there is a red fabric roundel decorated with floral motifs made of metal threads and metal sequins embroidery (see below (d) Decoration).

Figure 2.3: (left) The roundel on the top of the Mitre
Figure 2.4: (right) The metal ornament on the top of the Mitre where a cross (missing now) and gem stones were placed, in higher magnification

Four bands made of the same fabric and with similar embroidered decoration start from that point and extend to the lower part of the Mitre, where a similar band covers the entire circumference. These bands divide the Mitre into four parts, each of which also bears roundels (two of them have been detached), decorated with floral motifs, similar to those placed at the top of the Mitre. Metal sequins of three different kinds as well as metal thread embroidery are also scattered in these parts.

Figure 2.5: Intermediate layer- It is visible the paper and the supporting fabric layer

b) Intermediate layer

As mentioned in Section 1.2.1, Mitres are made of paper, which covers the spherical mould, which in turn is covered with layers of fabric (Varvounis and Macha-Mpizoumi 2014). There are not any further information regarding the Mitre under study, however, the afore mentioned technique is confirmed by the visible intermediate layer of paper, which can, actually, be seen due to the loss of the outer fabrics. The support material under the paper comprises of 4 layers of thick off-white fabric (see *Figure 2.5*).

c) Inner layer

The last part of the Mitre is composed of an off-white fabric of a thin weave, which covers the entire inner surface. At the bottom of the Mitre, part of the brown fabric, used for the outer layer, is turned over and folded.

d) Decoration

Metal threads and sequins have been used for the decoration of the Mitre. Metal threads of *file* type*,* which is a metal strip wound around an organic yarn (Johansen 2004, Karatzani 2012) have been used for the embroidered decoration. The embroidered areas are filled with paper in order to create a textured surface (relief embroidery). A spiral wire has been also used for some details of the floral motifs as well as for the metal decoration placed under the ornament at the top of the Mitre (see *Figure 2.7*). This type of metal thread is so called *tirtir* (Johansen 2004, Karatzani 2012). A series of sequins decorate the outer side of the roundels. Some of them are sewed in place with thread; while others are secured with metal threads (see *Figure 2.6* and *2.8*). Four different types of sequins have been identified some of which are coloured red (see *Figure 2.8* and *2.9*).

Figure 2.6: Detail of the metal and the organic thread used for sewing the sequins

Figure 2.7: Metal decoration with tirtir type of metal thread

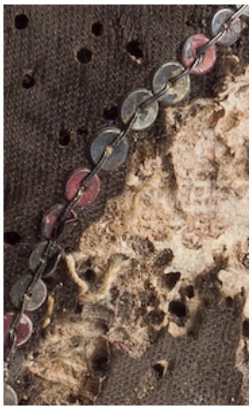


Figure 2.8: Simple and red coloured sequins

Figure 2.9: Three different types of sequins (gold, silver and silver with decoration)

2.3 Case Description

Figure 2.10: An over view of the Mitre's case

The case has a cylindrical shape and a lid at the top as one can see in Figure 2.10 (see *Figure 2* in Appendix 2 for more pictures of various details of the case). It has the following dimensions: height 26.5 cm, circumference 80 cm and thickness 2 cm. It is made of wood and is covered with leather that is black in colour. The leather has been fastened on the wood with metal nails and adhesive. On both sides of the main body of the case there is a leather belt with metal characteristics used for fastening the case. At the centre of the lid, there is a metal hoop, which apparently facilitates its removal. The inner side of the case is covered with paper serving as decoration, and as a protection for the Mitre placed in it.

2.4 Condition of the Mitre and the Case

The textiles that served the liturgical rites have suffered greatly from time. Apart from the inherent fragility of their fabric, especially the silk, their rich ornamentation with metal threads, gold and silver sequins, pearls and gemstones made them tempting targets for plunder at various periods (Woodfin 2004: 295).

The Mitre and the case are in medium condition. The types of degradation that observed at the two objects are mechanical, chemical and biological. More specifically, on the Mitre's surface there are missing areas and holes. As it is mentioned above two of the four roundels are missing (circular decorative objects made of metal thread embroidered fabric) probably by human actions while holes and fragile areas from use are observed. Distinctive are the holes by the action of insects, which cover most of the outer surface and penetrate into the intermediate layers. As far as the metal thread embroidery is concerned, that is generally well preserved, presents deterioration only in the lower part of the Mitre, in a specific area. In that area, some metal threads seem to have been detached and broken, deforming the initial aspect of the embroidery. The external layer (brown fabric) presents crushed and broken fibres and discoloration caused by ageing and light.

All the constituents of the case, i.e. wood, leather, metal parts and paper are deteriorated. The wooden parts, mostly at the lid, have been affected by insect's action. There are missing areas at the leather and it is also brittle (a loss of flexibility). Finally, the metal parts exhibit strong oxidation. Generally, a visible layer of dust and other pollutants covers the whole surface of both objects.

2.5 Previous treatments

No previous treatment of the Mitre was observed. On the contrary, the case does not seem to have been left intact: the use of white glue was attested; probably serving for re-joining deteriorated parts of the leather on the wood.

2.6 Storage condition

The Mitre and its case were transferred to the Ephorate of Antiquities of Messinia in 2006 and they have been placed at the storage of the Ephorate ever since in a wooden box. Unfortunately, the storage conditions before that date are not known. The storage area of the Ephorate is placed on the basement of the building. There is not any information available about the environmental conditions, and it was not possible to contact any measurements (temperature and relative humidity) in the area due to time limitations. It can be only mentioned that the wooden box used is made from cheaply commercial wood, which is not the appropriate container for such object. The wood has an acidic nature and contains other chemical components (Massmann 2000). It can be problematic because emits harmful acids and other substances, acting harmfully to the objects in direct contact, accelerating the deterioration processes (Massmann 2000, Texas Historical Commission).

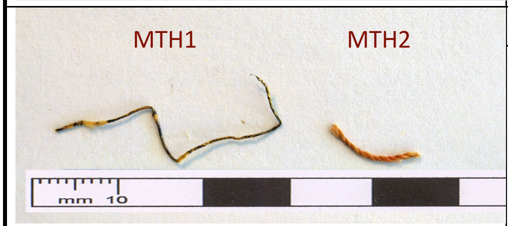
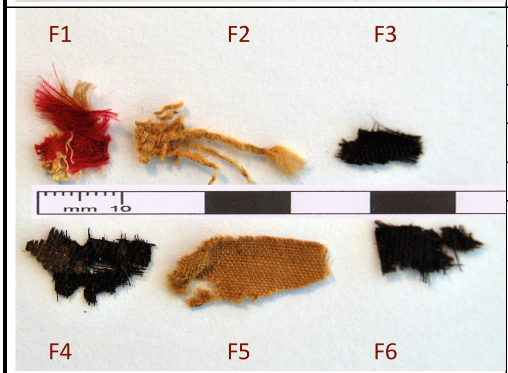
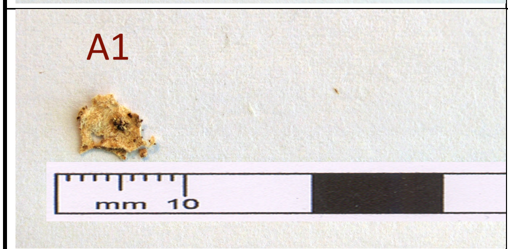
2.7 Samples

After the department of Byzantine and Post-Byzantine Antiquities of Athens granted the permission for sampling, this was carried out by the author, in order to obtain samples from the areas of interest. The samples were taken from already deteriorated areas without causing further damage to the object. Thirteen (13) samples were obtained in total, which represent all the construction materials of the Mitre. It is crucial to mention again that the sampling permission granted by the Ministry of Culture included only samples from the Mitre, and that's the reason why the case was not studied.

More specifically, samples of each of the three types of sequins (S1-S3) were taken (see samples S1, S2, S3 on *Table 2.1*), where S3 also contains the sewing thread. Sample S4 is part of the metal decoration at the top of the Mitre. The metal of S4 is thin and forms a cross, and is decorated with metal thread (tirtir). Parts of the metal thread (MTH1) from the main decoration of the object as well as from thread (MTH2) from the inner part of the Mitre, which seems to have been used for sewing the various layers of the fabric, were also taken.

Another group of samples consist of the fabrics that the Mitre is made of. Starting from the outer layer, we took a sample from the decorative band (F1) and from the brown fabric covering the biggest part of the object (F3). Immediately below this brown fabric, there seems to be a layer of paper, a sample (A1) of which was also removed. Next, there is an intermediate whitish part consisting of consecutive 4 layers made of the same fabric (sample F2). At the inner part of the Mitre, there is a brown fabric at the bottom that is possibly the continuation of the brown fabric covering the outer part of the Mitre (see sample F3). We removed part of the brown fabric from the inner side of the Mitre (i.e., sample F6 from the bottom and sample F4 from the top), in order to check whether samples F3, F4, and F6 belong to the same fabric. Last, the inner side of the Mitre is covered with a whitish fabric, sample of which was also removed (sample F5).

The following table (column 1: picture, column 2: name, column 3: material) summarizes all samples and figures 2.11 show the exact location where each sample is taken from.

<table>
<tr><td colspan="3">Table 2.1: Samples of the Mitre (photo, name and material)</td></tr>
<tr><td rowspan="4">
</td><td>S1</td><td>metallic sequin</td></tr>
<tr><td>S2</td><td>metallic sequin</td></tr>
<tr><td>S3</td><td>metallic sequin with sewing thread</td></tr>
<tr><td>S4</td><td>metallic ornament with metal thread</td></tr>
<tr><td rowspan="2">
</td><td>MTH1</td><td>metal thread</td></tr>
<tr><td>MTH2</td><td>thread</td></tr>
<tr><td rowspan="6">
</td><td>F1</td><td>fabric</td></tr>
<tr><td>F2</td><td>fabric</td></tr>
<tr><td>F3</td><td>fabric</td></tr>
<tr><td>F4</td><td>fabric</td></tr>
<tr><td>F5</td><td>fabric</td></tr>
<tr><td>F6</td><td>fabric</td></tr>
<tr><td>
</td><td>A1</td><td>paper</td></tr>
</table>

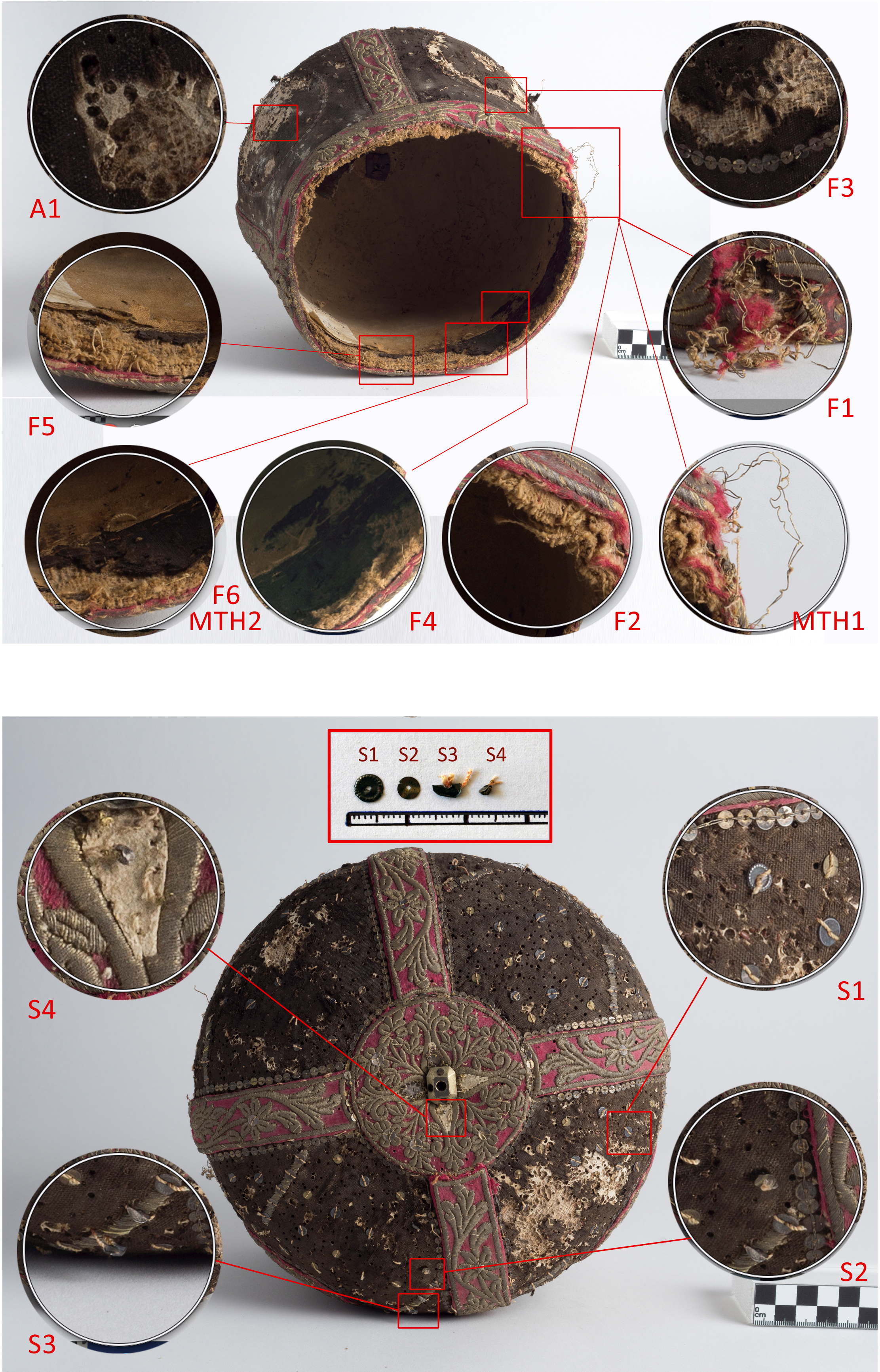


Figure 2.11: Depiction of sampling areas on Mitre

CHAPTER 3
Construction Materials and Techniques

In this chapter, a brief reference to the construction materials of the Mitre is given. The Mitre's construction materials are presented one by one, followed by the basic information that every researcher should look for.

3.1 Textiles

The various weave types are used to create fabrics with different textures and appearances. The most common weavings are: plain, twill and satin (see *Figure 3.1*), creating fabrics that differ in the arrangement of the warp and the weft yarns. Specifically, in the plain weave, which is the simplest weave, the weft yarn passes over and under one warp yarn at a time (or two and two). In the twill weave the weft yarn goes over and then underneath two warp yarns and then the pattern is moved on the left or on the right forming a diagonal surface pattern, and finally in the satin weave, the weft yarn travels over four or more warp yarns, and then underneath one warp yarn (it works also for the weft yarns) (Hatch 1993: 325-326).

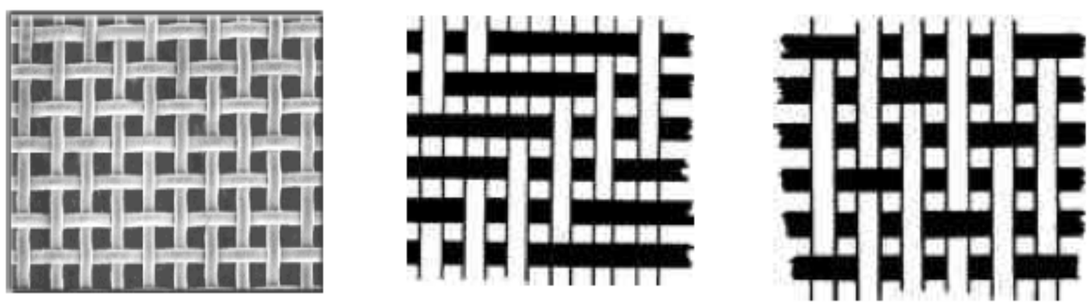


Figure 3.1: The most common weave patterns[12]

[12] http://www2.rcscsd.org/forensics/files/L_07x01_Identification%20Of%20Fibres.pdf

As far as the yarn construction is concerned, it is interesting to look at the way that fibres are joined together by twisting them in a uniform direction. The direction, left or right, in which the twist is inserted into the yarn, is designated by the letters S or Z, respectively (see *Figure 3.2*) (Florian *et al* 1990: 90, Hatch 1993: 289). Some yarns are large enough or too small to see the direction of the twist or it is the case that the twist is not frequent, which gives the impression that there is no twist at all (Hatch 1993: 287).

The yarn may consist of one or more plies. Ply is a set of fibres twisted together once. The construction of the yarn may include a combination of more than one plies that usually made of the same fibre type and have a different twist direction (Johansen 2004). The single plied yarn is the simplest type and consists of one ply. It is used in the majority of fabrics for normal textile applications. In order to obtain special features to the yarn, particularly high strength and modulus, ply yarns are often needed. A ply yarn is produced by twisting two (two ply yarn) or more (three ply yarn etc.) single yarns together in one operation and a cabled yarn is formed by twisting together two or more folded yarns or a combination of folded and single yarns (see *Figure 3.3*)(Hatch 1993: 294, Kabir 2014, Hossain, *et al* 2016). The last type is mostly use in cords.

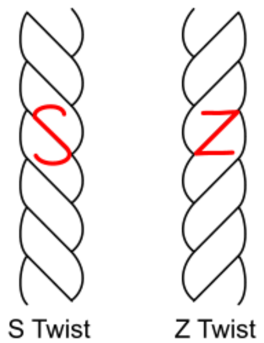


Figure 3.2: Direction of twist (Florian *et al* 1990: 90)

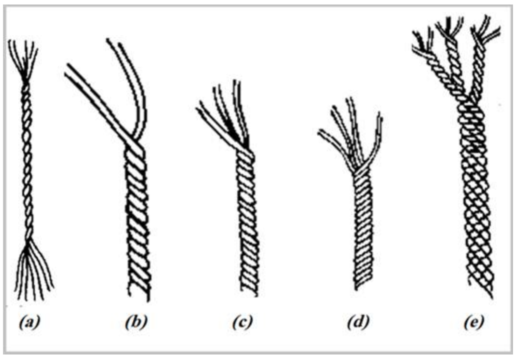


Figure 3.3: Yarn construction (a) simple ply yarn, (b) double ply yarn, (c) three ply yarn, (d) four ply yarn and, (e) cabled yarn (Hossain *et al* 2016)

Finally, the most important part in the investigation of a textile object is the definition of the source of the fibres. All textiles are made from fibres and until recently (19^{th} century) they were derived from natural sources. Natural fibres come from animals (wool and silk), vegetables (cotton and flax) and in some cases from mineral sources like asbestos and glass, and they present some distinctive characteristics (Canadian Conservation Institute 2010b, Hatch 1993: 164, Landi 1992: 8-9). Animal and vegetables fibres are built up from amino acid units into polypeptides, which are linked together to form protein, and cellobiose units into polymer cellulose, respectively (Landi 1992: 8-9).

3.2 Metal threads

Metal threads have been used in textile decoration for thousands years. Metal threads can have several types of structures. Generally, they are divided in two types (see *Figure 3.4*): a solid metal strip (lamellae) and a wire, both of which have usually been wound around a fibrous core (Jaro 2004, Karatzani 2007: 54). The metals that were usually used to make them are gold, silver, copper and the alloys of these metals, while zinc, nickel, and tin have been also used as alloying elements, (Karatzani 2007: 55, Rezic *et al* 2010). The fibres used for the core were usually made by silk, cotton and linen (Karatzani 2007: 54, Rezic et al 2010).

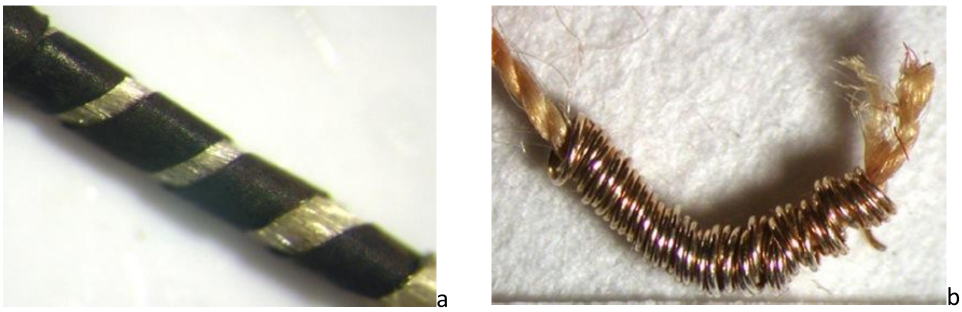


Figure 3.4: The most common types of metal threads, (a) strip wound around a silk yarn *file*, (b) wire wound around a silk yarn, *tir-tir* (Karatzani 2007: 54)

At this point, it is important to make a reference to the manufacturing technique of the metal threads. The first type, the solid metal strips, can be produced by cutting them from a thin metal foil. The other manufacturing method is the flattening of a wire by hammering or passing between rollers (Hacke *et al* 2004, Jaro 2003, Karatzani 2007: 64). Both of techniques make flattened metal strips ready for use as they are or by wounding around in a fibrous core. The average width of the strips used for making metal threads is between 0.02 and 0.04 mm (Jaro 2003, Karatzani 2007: 64).

For the production of metal wires several manufacturing techniques have been recorded. For example a metal bar/ingot is hammered out until a wire is obtained. The producing wire with this technique has not exactly round shape but it has a solid cross section and is characterised by the presence of longitudinal creases, because of the hammering. In some cases, the wire that produced by hammering then twisted as tightly as possible and is rolled between two flat pieces of wood (Karatzani 2007: 68-81). This wire has a solid, roughly round cross-section, and also has a more even diameter along its length compared to the wire produced with the first method (Karatzani 2007: 68-81). We conclude this reference by the last type of wire manufacturing technique in which a metal ingot is passed through a series of holes of a draw plate (Jaro 2003, Karatzani 2007: 68-81). This technique involves the gradual reduction of the thickness of a metal rod after each pulling. The characteristic of this wire is the circular shape and parallel striations are presented along the length of the wire, from the draw plate or the signs of the rolling process in the cases that the wire has been flattened to produce a strip.

3.3 Metallic sequins

Sequins maybe referred to as spangles, paillettes or paillons, and they are used for decorative purposes (Nehring 2005, Paulocik and Williams 2010). They are disk-shaped beads with a single hole in the middle. A threaded needle passes through that hole, which is then sewn on the fabric. The sequins come in various sizes and shapes. Until the late 19th century, most sequins were made from metals, such as gold, silver, steel and brass (Curkovic and Ujevic 2010, Paulocik and Williams 2010, Rezic et al 2010).

The most common type of sequins is made by flattening a spiral wire with a planishing hammer (O'Connor and Brook 2007: 234, Olaru et al. 2013, Karatzani and Reheren 2006, Paulocik and Williams 2010). Such sequins are usually not perfectly circular and have an indent on one edge, where the join runs through to the stitching hole (O'Connor and Brook 2007: 157). They can be found in various dimensions depending on the diameter of the wire used for their production. Another group of sequin beads are those obtained by stamping and these are perfectly round in shape (Balloffet 2010, Olaru et al. 2013).

3.4 Paper

Paper is composed of cellulose fibres derived from plants (Daniels 2006). These fibres are held together by lignin, which is the “natures glue” for the fibres. The fibres can be derived either directly from plants (primary) such as cotton, flax or hemp fibres or indirectly from vegetable products (secondary) recovered paper or even by animals (silk fibres, hairs etc.) or by minerals and technically made fibres (Vlessas and Malakou 2010).

The papers that made of primary raw materials are divided into two categories, the non-wood or vegetable fibres and wood fibres (Vlessas and Malakou 2010). The non-wood fibres used exclusively for the paper production from its invention till the mid-19th century (Daniels 2006, Vlessas and Malakou 2010). The increasing demand of the paper in the Western world and the invention of typography, attenuate completely the use of non-wood fibres and increased the use of wood fibres because of their abundance (Maniati and Papadopoulou 2006). The other categories are out of the scope of the present study and they are not analyzed further.

A paper structure as bounded by its surface is composed broadly of fibres and voids between fibres (American Society for Testing Materials 1963). Most of the fibres have characteristic features when viewed on a microscope that can be easily used to identify their origin e.g. cotton and linen as far as to discern the wood type that came from (Daniels 2006). Although some scientists prefer to use a scanning electron microscope and polarising light microscope in which interior features can be seen the identification is greatly facilitated by wetting the paper and separating the fibres (Daniels 2006).

CHAPTER 4
Methodological approach

In this chapter, the methodology used for the investigation of the samples will be discussed, as well as the analytical study of the samples, i.e., the results that arose from the various techniques applied and what those results indicate regarding the materials of the Mitre. At the beginning a brief description of the analytical techniques applied will be given followed by the description of the equipment used for the study of the samples and the operating settings as well as the place that the examination was held. After that, we present the results of the analyses we conducted (section 4.3), which are discussed by material: that is, fabric (section 4.3.1), metallic decoration (section 4.3.2), adhesives and paper (section 4.3.3).

4.1 Analytical Techniques

For the decision of the most appropriate analytical techniques for any study, it is important to take into account several criteria. The first concern is the establishment of the research questions, consequently, the selection of the techniques that answer the research questions, concluding with the availability and accessibility of equipment were two other very important issues for this project.

The **optical microscopy (OM)** and **Scanning Electron Microscopy (SEM/EDS)** are by far the most frequently used methods for the study and analysis of textiles, fibres, papers, metal threads and metallic objects. The chemical composition of the metal threads and sequins are usually analysed by SEM with energy dispersive spectrometry (EDS). The **Fourier transform infrared spectroscopy (FTIR)** was selected as an additional technique for the identification of the organic material.

Optical Microscopy (OM)

Optical microscopy is a quick method for identifying a broad range of materials including textiles and fibres one can obtain coloured images, which can be used for the documentation of samples. It is a method employed for the surface examination of objects with a magnification range of x8-x40 in stereo-microscope and x50-x1000 in metallographic microscope. For the latter microscope, the samples need to be flat and polished by placing them between glass slides.

Scanning Electron Microscope/ Energy Dispersive Spectrometry (SEM/EDS)

The SEM permits the high magnification (up to about x 100.000) and the detailed observation of the external structure of objects, making it a very useful tool for the identification and documentation of morphological characteristics. The EDS system gives an elemental analysis of the sample. The surface of the sample is scanned using a beam of high-energy electrons. The incident electrons will give rise to different types of emitted particles or radiation depending on the type of interaction between the electron beam and the sample. Secondary electrons and backscattered electrons emitted from the sample may be captured to yield high magnification images of the sample surface. Furthermore, the electron beam on the sample will also generate other signals, such as x-rays with characteristic energies. With a built-in energy-dispersive x-ray (EDX) spectrometer, the elemental composition of sample can be identified from the x-ray spectrum.

Fourier transform infrared spectroscopy (FTIR)

FTIR is a tool for identifying the types of chemical bonds in a molecule by producing an infrared (IR) absorption spectrum. When IR radiation interacts with a sample, radiation of the same frequency as that of inter-atomic bond vibrations is absorbed. Every molecule will have its own characteristic IR spectrum, akin to a fingerprint, which corresponds to the specific types of bonds found within it; hence the nature of the molecule can be deduced. Attenuated total reflectance (ATR) is one of the sampling methods available to use with the technique. The sample is placed in contact with a crystal of high refractive index, where total internal reflection will occur along the crystal–sample interface. The IR beam enters the crystal and is internally reflected along the length of sample; it interacts with the surface of the sample through a phenomenon known as the evanescent wave effect, before leaving the crystal and being recorded by a detector.

4.2 Equipments

The analytical techniques used in the current study are Optical Microscopy, Scanning Electron Microscope with Energy Dispersive Spectrometry (SEM/EDS) and Fourier transform infrared spectroscopy (FTIR).

The study by the optical microscope was held at the University of Peloponnese (UOP) in Kalamata. The laboratory is equipped with an optical stereo-microscope Leica, a LED optical microscope Moritex and a Polarised microscope Leica connected with PC and controlled by Leica MC120 HD software. The fibres are laid out on a glass microscope slide and mounted under a cover-slip using a liquid mountant (glycerin and water 1:1).

The SEM analysis took place at the UOP in Kalamata and at the Technological Educational Institution of Athens (TEI of Athens) in the Conservation of Antiquities and Works of Art department. The UOP laboratory is equipped with a low vacuum SEM model JEOL JSM-6510LV with Energy Dispersive Analyser EDS (OXFORD Inca energy 250 X-ct systems) while TEI of Athens has SEM model JEOL JSM-5310 equipped with EDS Energy-dispersive X-ray spectroscopy (OXFORD LINK ISIS L310).

All the samples were placed on metal stubs covered with shelf adhesive carbon tape before being placed in the SEM in order to be conductive. The samples were examined, using the secondary electron detector, a medium aperture, approximately 40 spot size, a working distance of 16-17 mm and a 20 keV accelerating voltage.

FTIR analyses held at TEI of Athens by Dr Stamatios Bogiatzis[13] who also performed the interpretation of the results obtained. The FTIR-ATR spectrometer is Perkin Elmer (Spectrum GX) with diamond cell.

[13] Special thanks for the perform and the interpretation of the results

4.3. Results

4.3.1. Identification of fabric

As mentioned above (see section 2.7 Samples) the group of fabric samples (F1, F2, F3, F4, F5, F6 and MTH2) are contained all the fabric types and threads that were used for the construction of the Mitre. The F1 sample was taken from the decorative band in outer layer and F3, F4, F6 from the brown fabric covering the biggest part of the Mitre. Sample F2 was taken from the whitish fabric at the intermediate part and F5 from the whitish fabric on the inner side. Finally, the thread sample MTH2, which was taken from the inner part of the Mitre, seems to have been used for sewing the entire object.

An identification procedure using the optical microscope and the SEM for a more detailed analysis was carried out, which revealed the weave type of the fabric, its yarn construction and the origin of the fibres.

a) Outer layer – red fabric: sample F1

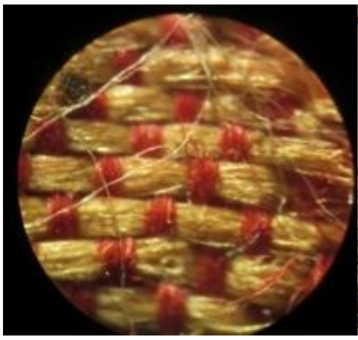


Figure 4.1: Satin weave pattern of Sample F1, OM X5

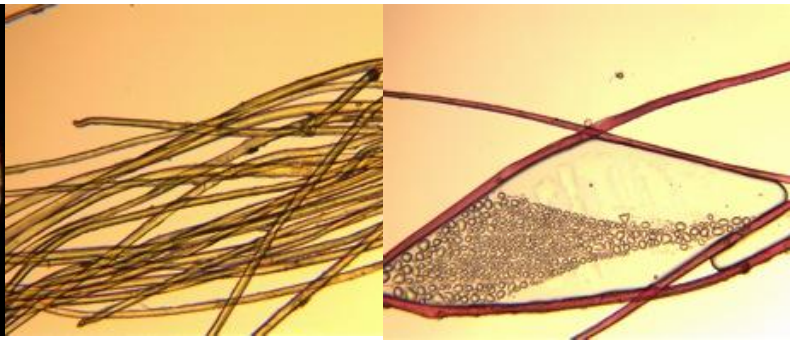


Figure 4.2: Silks fibres from sample F1, OM X10 white (left) and red (right)

By the examination with optical microscope in magnification of X5, a satin weave pattern 4:1 was identified, in which one weft (red) crosses four warp threads (white) (see *Figure 4.1*). Fibres were removed from the sample for further investigation. As we can see in *Figure 4.2,* the fibres look like a cylindrical, smooth rod with periodic bulges, which is the characteristic morphology of silk (Canadian Conservation Institute 2010). Finally, no twisting direction was detected.

b) Outer layer – brown fabric: sample F3, F4 and F6

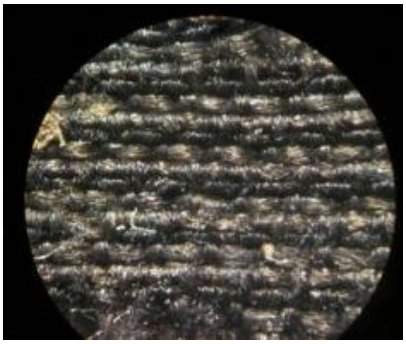


Figure 4.3: Twill weave pattern of sample F3, OM X5

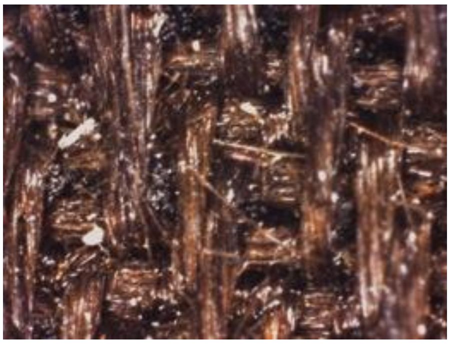


Figure 4.4: Twill weave pattern of sample F3, Usb-microscope X200

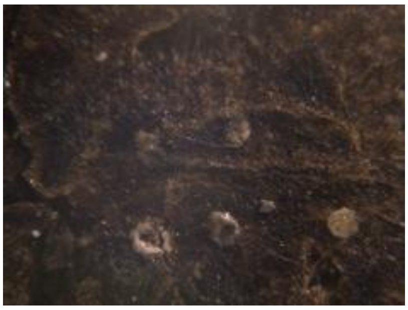


Figure 4.5: Layer of the adhesive on sample F4, OM X5

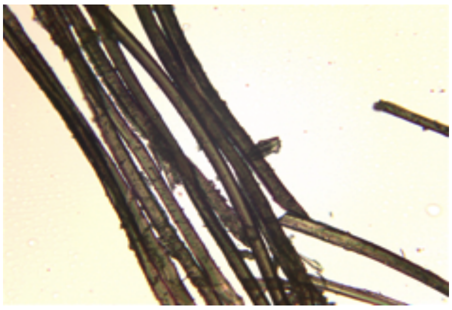


Figure 4.6: Silk fibres from sample F3, OM X20

Detailed observation revealed that samples F3, F4 and F6 come from the same type of fabric. The weave pattern is identified as twill, where the threads pass over and under three threads (see *Figure 4.3* and *4.4*). Moreover, the fibres that were removed have the characteristic morphology of silk too (see *Figure 4.6*), without a twisting direction. Finally, the use of adhesive was detected in all samples (see *Figure 4.5*), which was further investigated by FTIR by Dr S. Bogiatzis (Department of Conservation of Antiquities and Works of Art at TEI of Athens).

The FTIR analysis was applied only in sample F3 as a representative sample. The analysis showed that the fibres are made of silk, confirming the previous examination by OM. "More specifically, by the examination of the fibres, a protein-based material is identified. The relatively low values of amide I and II offer evidence for a crystalline material (as ordered crystalline structure favours intense hydrogen bonding which lowers the absorbance frequencies (in cm^{-1}). In comparison with a standard FTIR spectrum of reference material it seems that the textile fabric is possibly silk; however, (a) the missing amide B band, (b) a small shift of amide II (towards higher wave numbers) and (c) the broader amide A (3282 cm^{-1}) allow an estimation for either poorer quality of initial textile fabric or relatively degraded material. Furthermore, a collagenous protein material (possibly, animal glue) is identified on the surface of the fabric. Inert material (possibly silicates) is also evident”. (Dr Bogiatzis, p.c. Dec. 23 2016).

c) Intermediate layer: sample F2

Figure 4.7: Plain weave pattern of sample F2, usb-microscope X50

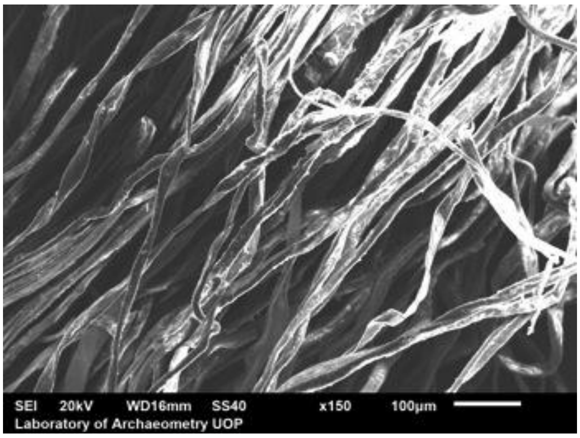


Figure 4.8: Fibres from sample F2, SEM X150, photomicrograph showing that the fabric comprises of cotton fibres

The intermediate layer has a simple weave structure (see *Figure 4.7*), named *plain*, as mentioned above. It is made by cotton fibres of various thicknesses (see *Figure 4.8*). Cotton fibres under magnification look like a ribbon with twists (convolutions) at intervals along the length of the fibres (Canadian Conservation Institute 2010). This was observed in optical microscope as well as in SEM, which also showed that we have a clear case of a yarn construction with Z twist.

d) Inner layer: sample F5

A thinner cotton fabric makes the inner layer displaying the same characteristics that sample F2 has (see section (c) above for details and corresponding figures below).

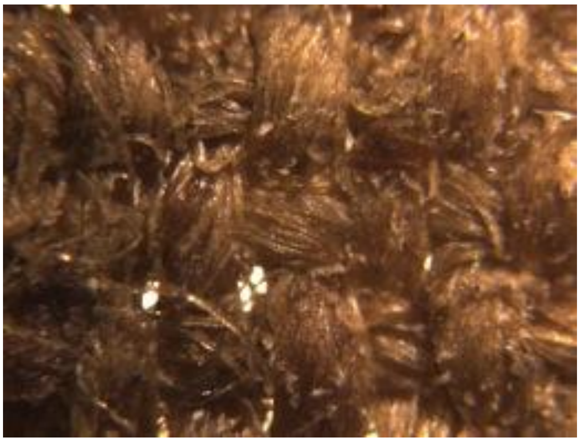


Figure 4.9: Balance plain weave pattern of sample F5, OM X5

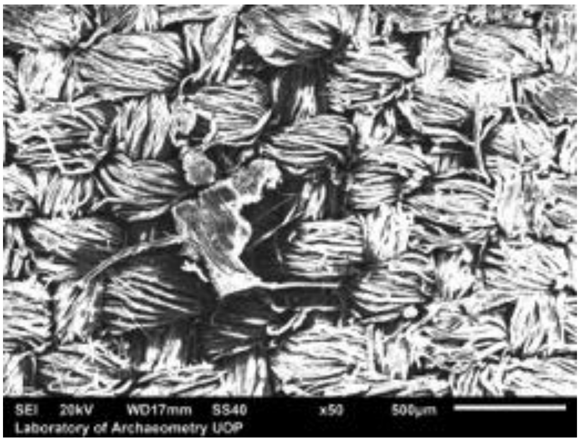


Figure 4.10: Balance plain weave pattern of sample F5, SEM X50

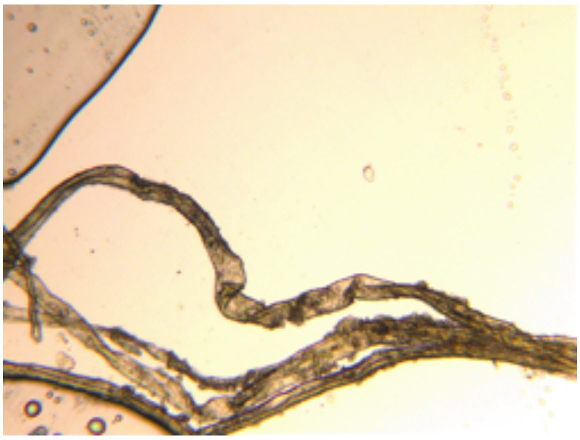


Figure 4.11: Cotton fibres from sample F5, OM X10

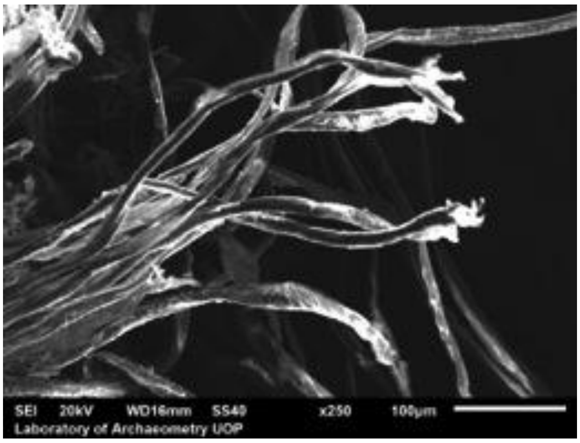


Figure 4.12: Cotton fibres from sample F5, SEM X250

e) Sewing thread: sample MTH2

The sample MTH2 consists of the sewing thread used in the Mitre for various purposes. The thread consists of two yarns twisted in Z shape (2-ply yarn) as we can see in *Figure 4.13.* Finally, it is made of silk fibres, as it is detected in optical microscope, where Figure 4.14 was taken.

Figure 4.13: The sewing thread used in the Mitre, sample MTH2, OM X5

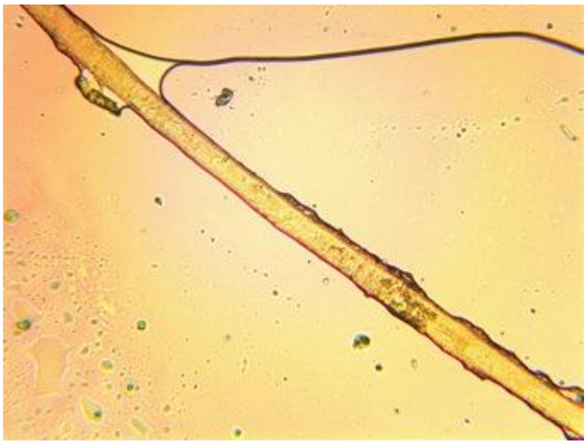


Figure 4.14: Silk fibre from sample MTH2, OM X20

4.3.2 Study of the metallic decoration

As mentioned in section 2.2d, metal threads and metallic sequins have been used for the decoration of the Mitre. For both of these materials an identification procedure using an optical microscope and SEM for a more detailed analysis was carried out.

More specifically, metal thread and sequin manufacturing techniques have been investigated by scanning electron microscopy (SEM). The core fibre was identified by using optical microscopy and scanning electron microscopy (SEM). The chemical composition of the metal threads and sequins was determined by using SEM with energy dispersive spectrometry (EDS). Deterioration extent of metal threads and sequins was carried out with SEM. Finally, the composition of red pigment that appears on some of sequins was detected by SEM/EDS and Fourier transform infrared spectroscopy (FTIR).

a) Metal thread: sample MTH1

The metal thread consists of a solid metal strips wound around a silk core, as we observed by the investigation in the optical microscope and SEM (*see Figures 4.15* and *4.16*). The sample exhibits S twist of the metal coils. In Figure 4.16 metal corrosion products are observed which are further analysed by EDS.

The EDS analysis reveals that the principal component of the metal thread is silver (Ag) in concentration of 27.56%. The presence of gold (Au) in a lower quantity (6.41%) suggests most likely that the thread is gilt, which validates its yellowish colour.

Furthermore, the presence of chlorine (Cl), which is a contaminant, points to the metal being corroded (Mohamed *et al* 2016), as seen in table 4.1. Furthermore, the significant percentages of elements such as Si, Ca, Mg, Al and Na indicating that the metal threads are very dirty and were covered with dust and other particles.

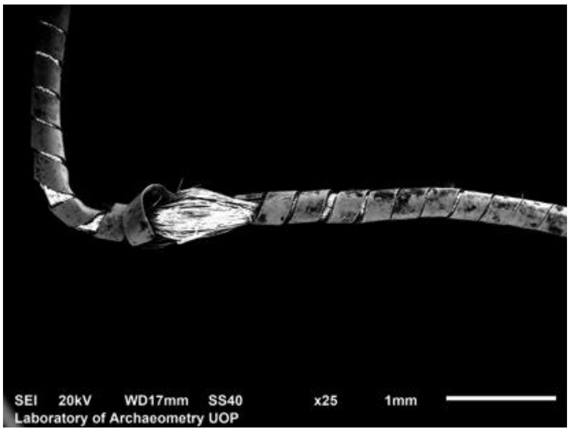


Figure 4.15: A photomicrograph of the metal thread X25

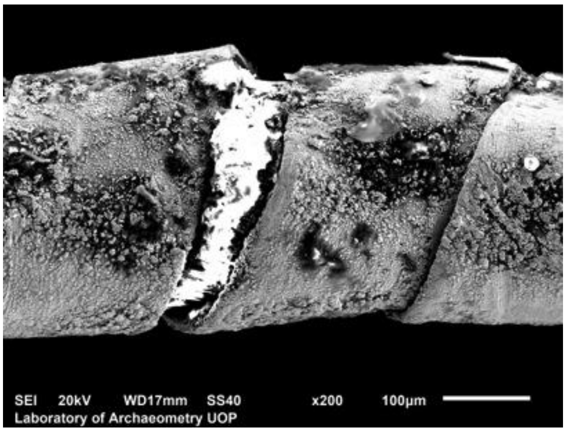


Figure 4.16: A detail of the sample in higher magnification. The condition of the metal surface is also shown

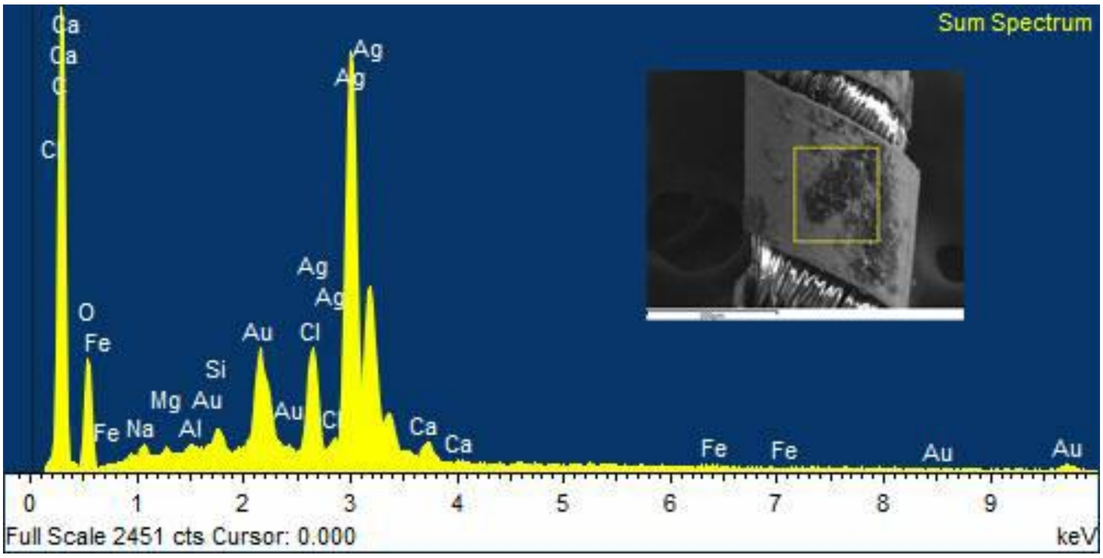


Figure 4.17: SEM-EDX analysis of the metal thread, indicating that the most significant element present is silver (Ag). The yellow box indicates the area scanned (x100)

Table 4.1: SEM-EDS results expressed in mass percentages (wt%)											
Sample	**Mass percentages (wt%)**										
	C	**O**	**Na**	**Mg**	**Al**	**Si**	**Cl**	**Ca**	**Fe**	**Ag**	**Au**
MTH1	41.51	20.24	0.42	0.18	0.16	0.42	2.43	0.66	0.02	27.56	6.41

b) Sequins: sample S1

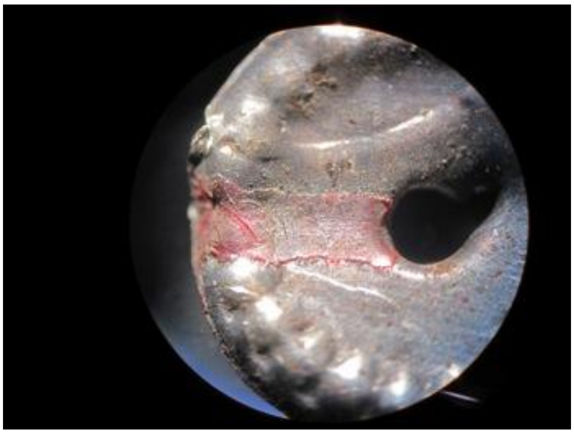


Figure 4.18: Sequin S1, OM X5

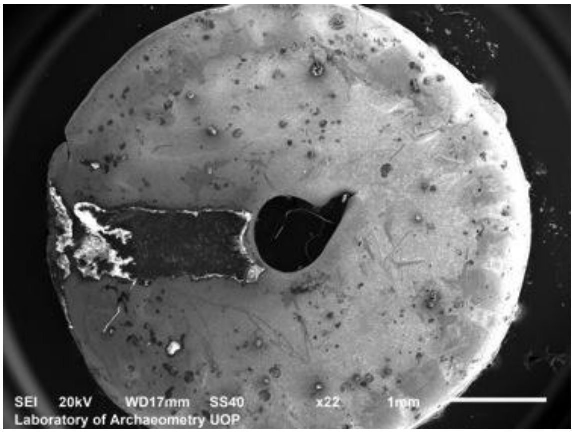


Figure 4.19: A photomicrograph of the sequin S1

The sequin named S1 has a spherical shape with decoration at the edge. It is constructed by stamping and it has a perfectly round shape with approximate diameter 4.75mm. By the observation in optical microscope, a red line at the area where the sewing thread was attached to the textile was observed (see *Figure 4.18* and *4.19*). This indicates that the sequin was fully covered with a red coating and this was protected by the sewing thread. The read coating was further investigated by FTIR (see *Figure 4.21*).

The SEM-EDX analysis (see *Figure 4.20*) of the sequin revealed that the principal component is silver (Ag). The FTIR analysis revealed that the sequin was possibly coated with silicates. Furthermore, a collagenous protein material (possibly gelatine) was identified on the surface of the object. The results of FTIR analysis in conjunction with the presence iron (Fe) provide information for the red coating of the sequin probably the gelatine was used as carrier for the red pigment (Dr Bogiatzis, p.c. Dec. 23, 2016).

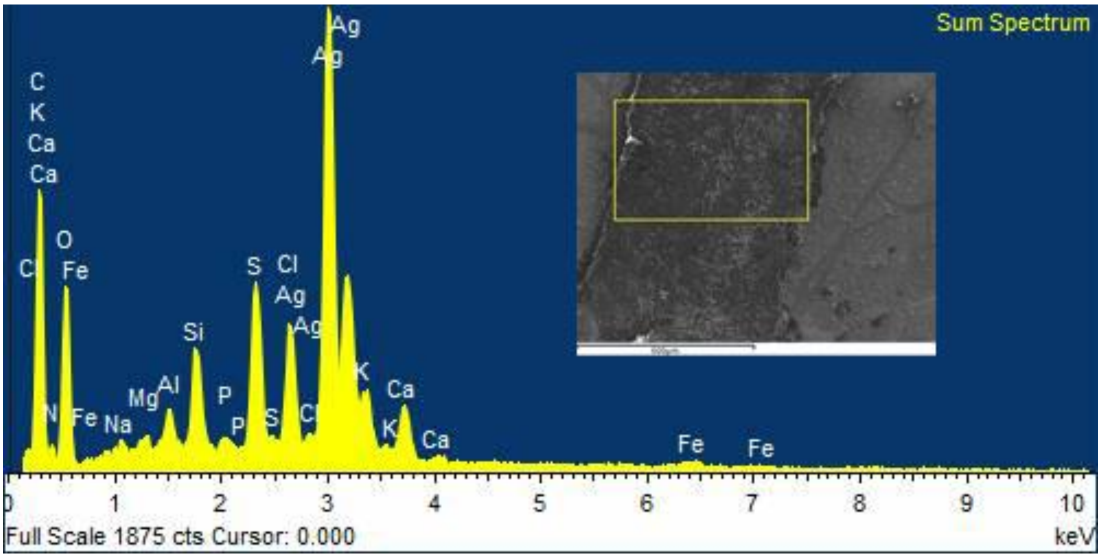


Figure 4.20: SEM-EDX analysis of the sequin, indicating that the most significant element present is silver (Ag). The yellow box indicates the area scanned (x100)

Table 4.2: SEM-EDS results expressed in mass percentages (wt%)

	Mass percentages (wt%)														
	C	**N**	**O**	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**K**	**Ca**	**Fe**	**Ag**	**Cu**	**Au**
S1	27.51	12.49	27.06	0.26	0.25	0.53	1.46	0.23	2.83	2.21	0.61	1.51	0.35	22.70		
S2	28.70		18.00							5.59				14.28	17.82	15.62
S3	11.15		14.27		0.40		0.52		2.64	3.57				67.46		
S4 metal	19.96		24.62				0.80		0.77	1.73		0.68		53.72	0.72	
S4 wire	13.61		7.45							0.27				16.14	30.23	32.30

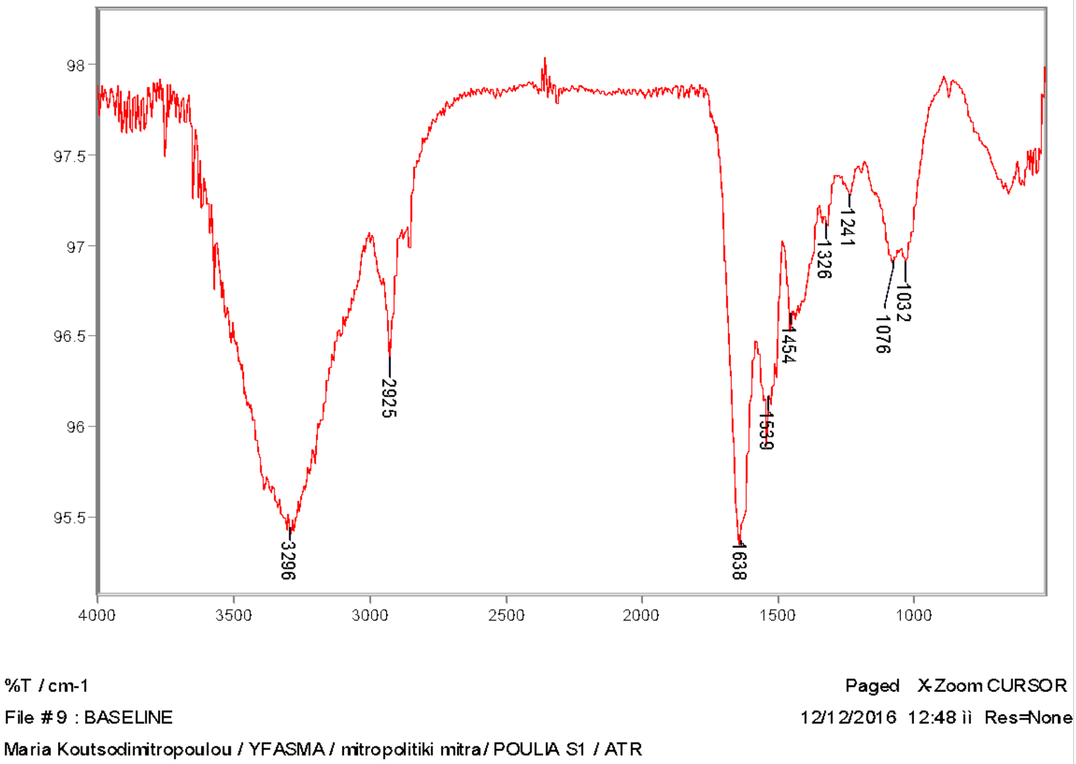


Figure 4.21: FTIR spectra from the red area of the sequin

c) Sequins: sample S2

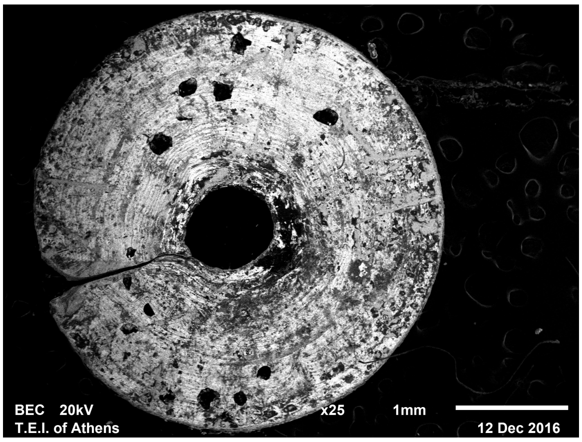


Figure 4.22: A photomicrograph of the sample S2

The sequin S2 is made by flattening a spiral wire, information that is evidenced from the existence of a line crossing the hole and the edge (see *Figure 4.22*). It is not perfectly circular and its diameter is around 3.58-3.79mm. The SEM-EDX analysis revealed the presence of gold (Au), of silver (Ag) and of copper (Cu) as one can see in the EDX spectrum (see *Figure 4.23*). The existence of the different bright lines on the surface of the sequin indicates that it is gilt. It possibly comprises of a silver-copper wire, which was gilt.

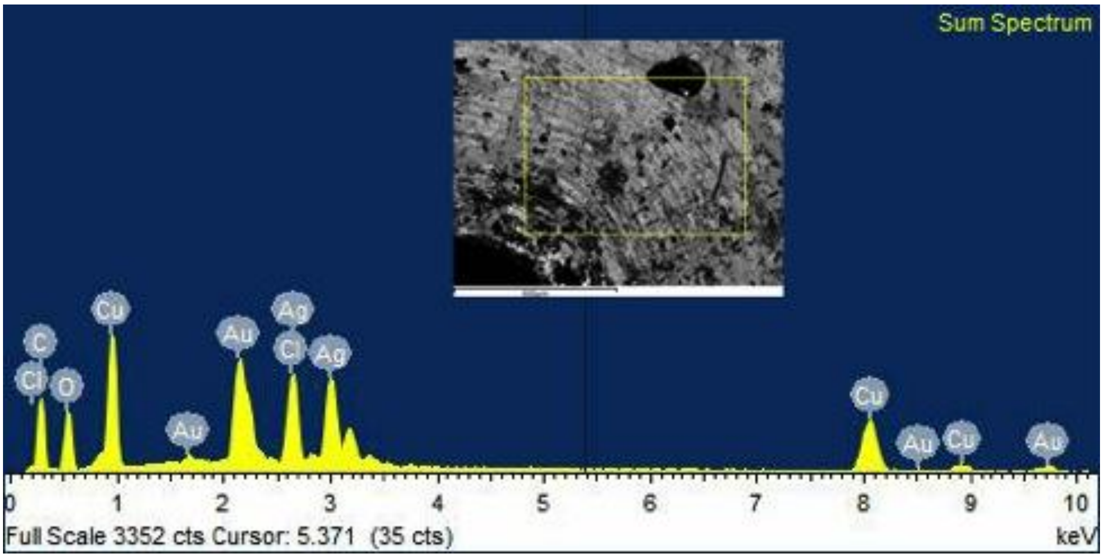


Figure 4.23: SEM-EDX analysis of the sequin, indicating the presence of gold, of silver and of copper. The yellow box indicates the area scanned (x100)

d) Sequins: sample S3

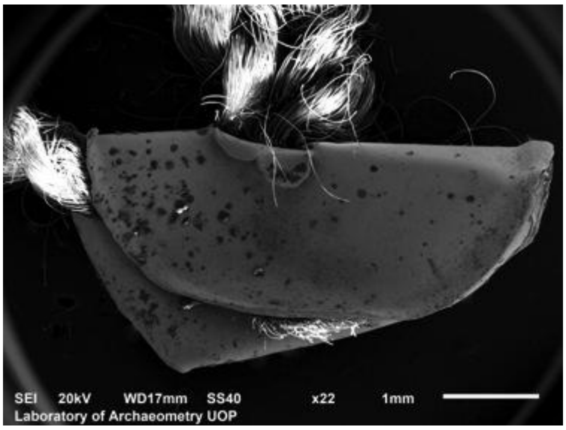


Figure 4.24: A photomicrograph of the sample

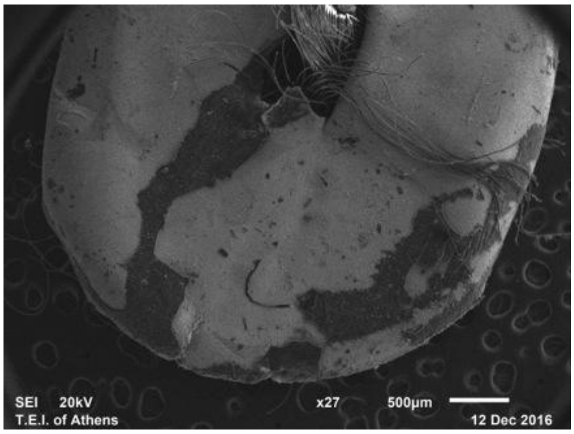


Figure 4.25: A photomicrograph of the "opened" sample

Sequin S3 exhibits the same characteristic as sequin S1. It has a spherical shape with no decoration. It is constructed by stamping with approximate diameter 4.80mm. The SEM-EDX analysis (see *Figure 4.26*) revealed that the principal component is silver (Ag), too. Moreover, a silk thread is observed on the sequins, which is used for sewing it on the fabric. After we flattened the sequin, a red coat was also revealed (see *Figure 4.25*), which was studied with FTIR and showed that it comprises of a collagenous protein material (possibly gelatine). Inert material (possibly silicates) is also evident (Dr Bogiatzis, p.c. Dec. 23, 2016).

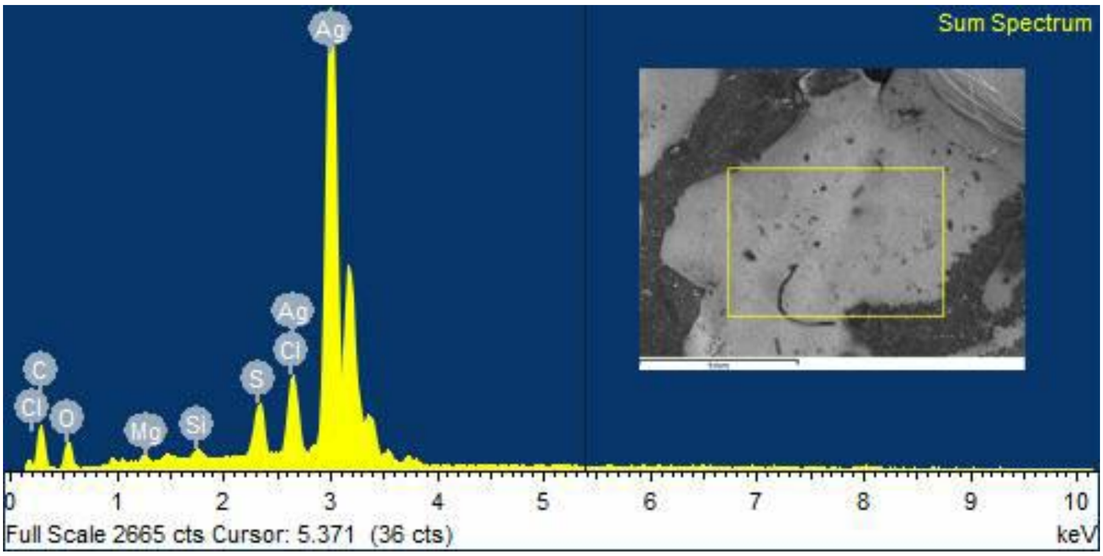


Figure 4.26: SEM-EDX analysis of the sequin, indicating that the most significant element present is silver (Ag). The yellow box indicates the area scanned (x100)

e) Metallic ornament with metal wire: sample S4

Figure 4.27: A photomicrograph of the sample

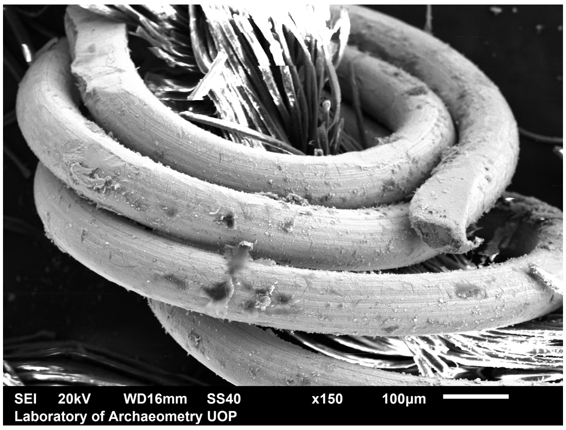


Figure 4.28: A photomicrograph of the sample

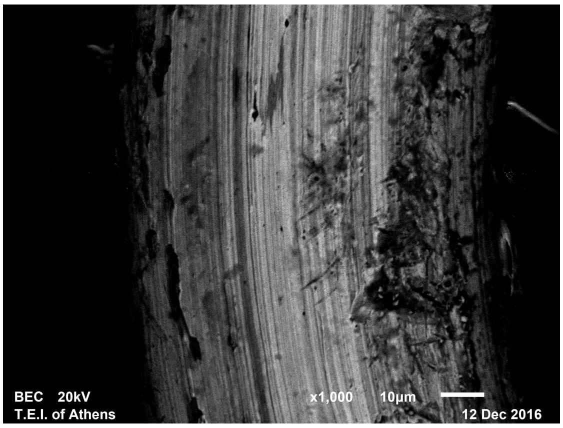


Figure 4.29: The characterisitic parallel lines of wire produced by pulling a gilt metal rod through a draw plate (SEM)

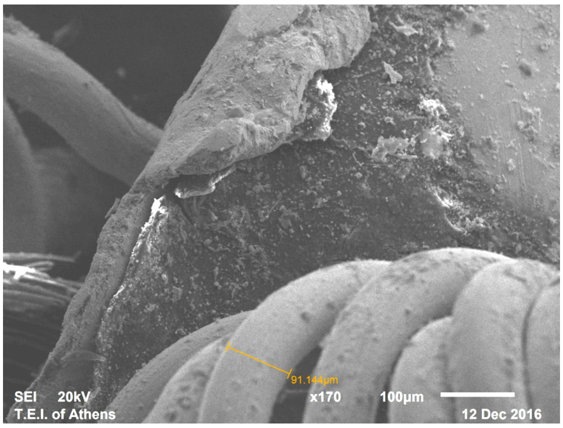


Figure 4.30: The thickness of the wire is 91µm (SEM)

Sample S4 consists of a piece of metal from the metallic ornament, which is located at the top of the Mitre, and a metal thread that was used for its decoration (see *Figure 4.27*). The metallic ornament is made of silver (Ag), as the SEM-EDS analysis revealed. As far as the metal thread is concerned, it is a wire, with thickness 91µm (see *Figure 4.30*), wounded around a silk core (tirtir). The metallic wire is examined by SEM-EDX analysis, which revealed the presence of gold, silver and copper but the presence of the parallel lines on its surface indicate that it was gilt. Furthermore, these lines are the main indication for the manufacturing technique used for its production, namely by pulling a gilt metal rod through a draw plate, as it is clearly sown in figure 4.28 (Karatzani 2007: 68-81).

4.3.3 Identification of the paper and the adhesive

As mentioned in Section 1.2.1, the Mitre is constructed of multiple layers of fabrics and paper, which cover a mould. The layers have been attached to each other by the use of an adhesive.

By the observation of the fabric as well as of the paper samples in the optical microscope, the presence of the adhesive was detected. The extensive study of all samples was not possible, for that reason the fabric sample F3 was selected to be analysed, as a representative sample, as mentioned in section 4.3.1 (b). The use of adhesive was further investigated by FTIR by Dr S. Bogiatzis. The results indicate the use of collagenous protein material, possibly being animal glue on the surface of the fabric. The spectrum of the glue is displayed in *Figure 4.31* and the spectrum of the reference sample of animal glue (rabbit bones glue) is in Appendix II *Figure 5*. A comparison of the two spectra reveals that we are dealing with the same material.

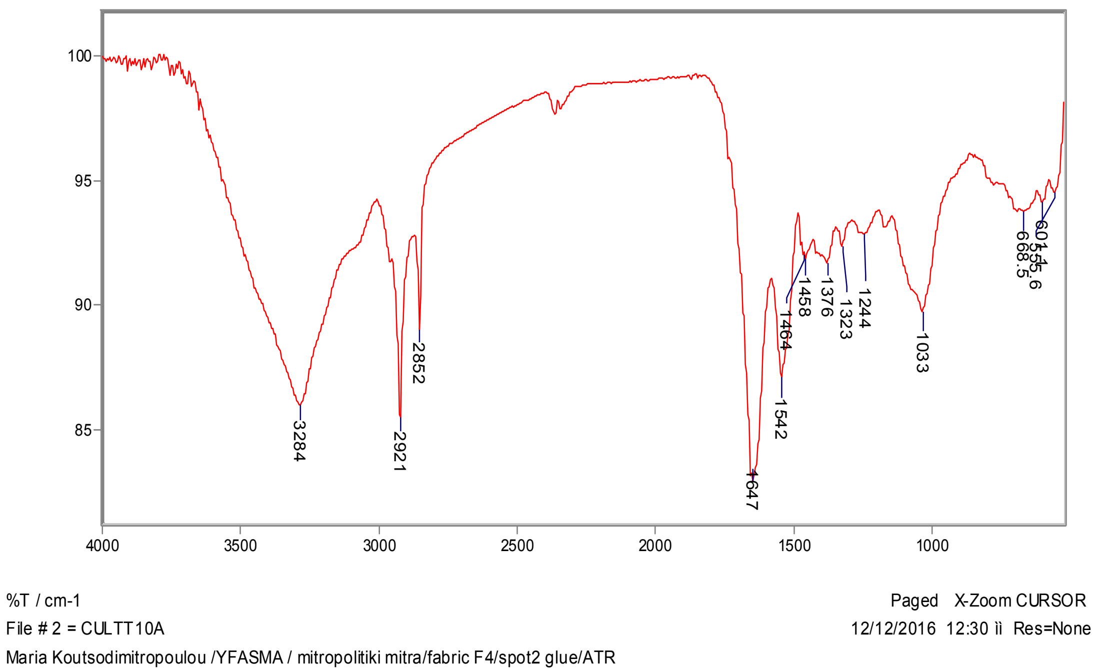


Figure 4.31: FTIR spectra of the adhesive (collagenous protein material, possibly, animal glue)

As far as the paper sample is concerned, this was examined under the optical microscope and the SEM. Light microscopy is one of the simplest techniques used for acquiring information about fibres and paper structures, while the SEM is suitable for pulp fibre and paper studies and provides high-quality imaging with high resolution. Many fibres can be easily identified, e.g., cotton and linen, due to the characteristic features they present (Daniels 2006).

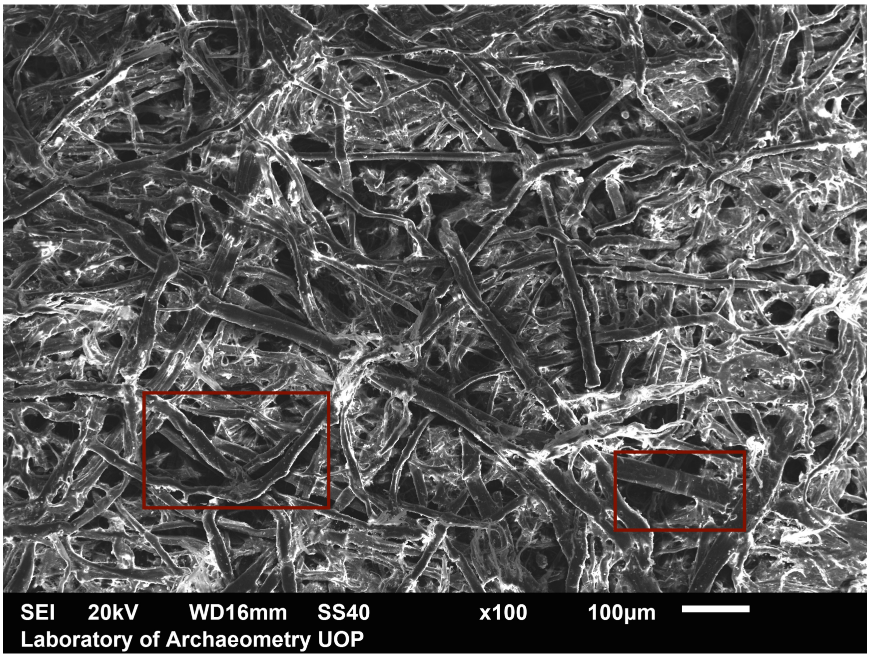


Figure 4.32: A photomicrograph of the paper sample

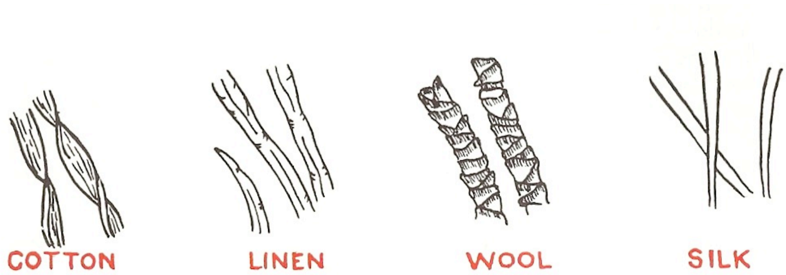


Figure 4.33: The appearance of natural fibres under microscope [14]

By the observation under the SEM, it is detected that the paper is made of cotton and flax fibres. As we can see in *Figure 4.32*, the existence of cotton fibres is clear (see the red box on the left side of the figure) as well as that of flax fibres (see the red box on the right side of the picture), which are confirmed by the database http://khartasia-

[14] http://artquill.blogspot.gr/2013/06/general-properties-of-fiber-polymers.html

crcc.mnhn.fr (see *Figure 4.33, 4.34* and *4.35*), comprising various images of paper fibres.

It should be noted that because of the papermaking process, including retting, leaching, cooking, cutting, pounded etc., the fibres exhibit a disordered distribution and morphology. For that reason, in the most part of the paper sample, the fibres are flat, and we cannot clearly see the characteristic twist along the cotton fibres or the basic characteristics of the flax fibres (see *Figure 4.32*).

Figure 4.34: Cotton fibre [15]

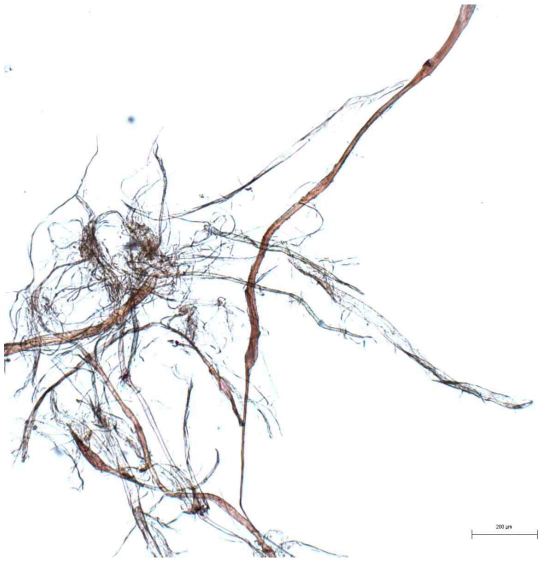
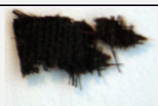
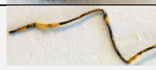


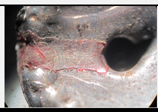
Figure 4.35: Flax fibre [16]

[15] http://khartasia-crcc.mnhn.fr/fr/common_names_fr/ceylon-tree-cotton

[16] http://khartasia-crcc.mnhn.fr/fr/common_names_fr/common-flax

Table 4.3: The summary of the results.

Fabrics			Decoration		
F1		Silk	**S1**		Silver (Ag)
F2		Cotton	**S2**		Gold (Au), silver (Ag) and copper (Cu) or Gilt silver and copper alloy
F3 **F4** ***F6***		Silk	**S3**		Silver (Ag)
F5		Cotton	**S4**		Silver (Ag) Wire: gilt silver and copper alloy
MTH2		Silk	**MTH1**		Silver (Ag)

Other materials		
A1		Cotton and flax fibres
Adhesive	Collagenous protein material (possibly, animal glue)	
Red pigment		Iron (Fe) and a collagenous protein material (possibly gelatine)

Chapter 5
Proposed Conservation Treatment

The Mitre is a composite object. It comprises of a variety of materials, each exhibiting different degradation signs, hence each having different preservation needs. A conservator is asked to conduct the most appropriate conservation plan, taking into account the needs of all the materials involved, thus, without harming them. This makes the conservation of composite objects a very demanding and complicated procedure.

The treatment procedures suggested for the Mitre in the current study have been designed based on the evaluation of its present condition, as this was examined extensively in the previous chapters. The chapter is arranged as follows: In the following section, a very brief reference to the degradation signs of the Mitre will be presented. Next, the conservation treatments will be discussed (section 5.2), divided into the cleaning methods and the stabilisation and filling of the missing areas of the fabric**.** The chapter concludes with the suggestions for the appropriate storage of the object as well as for the environmental conditions that should apply in the storage of the object.

5.1 Deterioration

A layer of dust and dirt has been observed on the Mitre's surface. Moreover, there are missing areas on the external layer (brown fabric) as well as at the lower part of the Mitre. One can detect holes at the biggest part of the outer surface, caused by the action of insects, which is also observed in the intermediate layers of the Mitre. As far as the metal embroidery is concerned, this presents deterioration only at the lower part of the Mitre, and more specifically, some metal threads of the embroidery seem to have been detached and broken. The sequins of the Mitre are generally in a good state, though in some cases they have almost been detached from the object, which is evidenced by the apparent displacement of the sewing thread.

A conservation plan will be designed in light of the deteriorated parts of the Mitre discussed above, including:

- the cleaning of the object
- the elimination of insects' action (disinfestation)
- the stabilisation and filling of the missing areas of the fabric
- the stabilisation of the metallic embroidery
- the design of the most appropriate storage for the object

5.2 Suggested conservation treatments

5.2.1 Cleaning

Cleaning involves the removal of the surface dust and dirt, which can be done mechanically and/or with solvent action e.g. wet cleaning etc. (Charola and Koestler 2006, Norton 1990). In the case of the Mitre, the mechanical cleaning was considered to be the most appropriate method. Wet cleaning was considered inappropriate due to the layered structure of the object.

The mechanical cleaning can in principle be done by the use of brush, vacuum suction or the combination of the two methods as well as by the use of vulcanised rubber sponge (Norton 1990). The vacuum suction allows dirt to be removed from the surface of the object with the minimum penetration to the lower layers. Vacuuming can effectively remove loose particulate matter, mould bodies, and some insect residue lying on the artefact's surface. To prevent the object's surface from being lost or damaged by the suction, a net screen could be placed over it or a fine net fabric can be tied over the end of the tube (see *Figure 5.1*).

The brush is used to flick dirt off the surface while the vacuum suction tube is held close in order to evacuate the loosened dirt. It is important to use natural brushes, as they gently attach to the sensitive surface of the object.

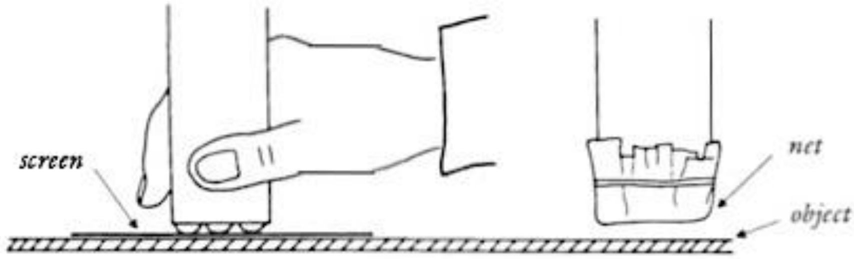


Figure 5.1: Vacuuming artefacts using a net screen or hose net (Norton 1990: 217)

The last method of surface cleaning is the use of a vulcanized rubber sponge (dry cleaning sponge) (see *Figure 5.2*). The vulcanized rubber has the characteristic to magnetize the dust by the gentle place of it on the textile surface. A swooping motion with light pressure would be enough to clean the object, while the remaining parts of the sponge on the surface of the object should be removed with the help of a brush.

Figure 5.2: Smoke sponges made of vulcanized natural rubber [17]

A combination of those three techniques is recommended for the Mitre to achieve the most successful cleaning. More precisely, the use of vacuuming in combination with the use of brush will ensure the removal of the biggest part of the dust and dirt of the Mitre. It will also remove the existing insects, but in the case of hidden insects or eggs thereof, it might not prove that effective. In this latter case, a disinfestation procedure would be instructive.

[17] http://www.preservationequipment.com/Catalogue/Cleaning-Products/Sponges-Cloths/Smoke-Sponges

For the disinfestation, the Metropolitan Museum of Art and other institutions suggest the use of a non-chemical treatment using oxygen-free environments. This approach has proven very successful for insect control and in some cases, it is able to kill some species of fungi, but has no effect on spores (Charola and Koestler 2006). In the book *Tool for Conservators: The Use of Oxygen-Free Environments in the Control of Museum Insect Pests* (Maekawa and Elert 2003) there are detailed instructions.

5.2.2 Stabilisation and filling of the missing areas of the fabric

In the case of missing areas of textiles, a piece of a new fabric is usually used as a support. Support patches are attached by stitching or by adhesive techniques. The chosen fabric should exhibit a visual and chemical compatibility with the original textile and should be dyed accordingly, if needed (Garside and Wyeth 2006). The areas that present detaching could be fastened by the use of stitches with a suitable thread, similar to the fibre of the original textile (Norton 1990).

In the case of the Mitre, the use of a silk crêpeline is recommended. It should be dyed in the appropriate colour and fastened with stitches by a thin silk thread. The edges of the holes as well as the detached metal threads of the embroidery can be secured with the same silk thread.

5.3 Storage suggestions

After the conservation treatment, it is essential for the preservation of any object as well as the object of the current study to be stored in an appropriate way.

All types of hats and headgears such as crowns, Mitres must be fully supported. The handbook of Museum management of the National Park Service, the Canadian Conservation Institute (13/12) and other Institutions suggest the commercial polyethylene foam heads or the purpose made supports for the objects with the same foam. This type of foam maintains the shape of the object (see *Figure 5.3*).

The following step is the production of an appropriate box for storing purposes is necessary (see *Figure 5.3*). A box with a lid made of acid-free materials is a good way to protect objects on open shelves. The box in question could be made by the conservators themselves (Norton 1990: Appendix 2) or can be purchased from conservation suppliers.

Figure 5.3: Custom-made boxes and supports [18]

5.4 Storage environment

Inappropriate levels of temperature and relative humidity promote deterioration to the textile objects. In general, cool and dry conditions are best for objects similar to the one under study. The relative humidity (RH) in the storage room should be between 45 and 55%, and the temperature should not exceed 18-20^{o}C (CCI Notes 13). To better control for the storage conditions, the use of humidity-buffering materials in the box is also necessary. The silica gel is the most usual type of such humidity-buffering material and is commercially available. For the insect control is recommended to use sticky straps in order to identify the presence and type of insects before taking any further actions such as the disinfestation of the entire storage area.

[18] http://www.arachovamuseum.gr/attachments/article/282/Ann%20French_Conservation1.pdf

Chapter 6
Overall discussion

In this chapter, we sum up the results obtained from the analytical investigation of all thirteen (13) samples obtained from the Mitre as well as the interpretation of those results. Following the structure of Chapter 4, we will discuss first the results of the fabric samples, we will continue with the metallic decoration, and conclude with the identification of the paper layer and the adhesive that was used in the whole object. After putting together the results presented in Chapter 4, a summary of the suggestions for the conservation treatment put forth in Chapter 5 taking into consideration the findings of our analyses. Finally, we discuss possible suggestions for future research on the Mitre, which is the focus of the present study, and also on the case of the Mitre, which had to be left out of this study.

6.1 Summary of analytical results

The Mitre, as a complex object, is constructed of various materials such as fabrics, metals, paper, etc. In order to conduct an appropriate conservation procedure, it is very important to deeply study and understand the materials that the object under investigation is made of.

As it is already mentioned, the Mitre is made of multiple layers of fabrics. The basic external fabric (samples F3, F4 and F6), which is coloured brown, is silk with a twill weave pattern. The twill weave makes fabrics durable, heavier, and wrinkle resistant. That was an apt choice for the external layer. As far as the choice of silk fabric is concerned, this gives an elaborate aesthetic to the object. The fabric was studied further with a FTIR analysis and the relevant results suggest either a poorer quality of the initial textile fabric or, most likely, a relatively degraded material, as a result of the oldness of the object and its poor storage conditions. The decorative band that was placed on the external side of the Mitre is made by silk fibres woven in a satin pattern (sample F1). The satin pattern is responsible for the smooth shiny surface of the band, which, together with the metallic embroidery decoration that it bears, makes the band more elaborate. The other fabric layers, of which one constitutes the intermediate layer (sample F2) and the other covers the inner side (sample F5) of the Mitre, display the same characteristics, with the only difference in the thickness of the fabric. The fist fabric is much thicker than the other one, which is more delicate. More specifically, the two kinds of fabric are made of cotton fibres woven in the simplest way (plain pattern). It was also observed that there is only one type of thread in the Mitre, which was used for sewing the various fabric layers and sequins. This thread (sample MTH2) is two plied and is made of silk fibres, which make it of high quality. The use of silk threads is not very common for simple sewing, such as that in the case of the various fabrics, described above.

The elaborate decoration of the Mitre consists of metallic embroidery and sequins, as well as metallic ornaments, placed at the top of the Mitre. The latter are formed of a compact metallic ornament, which was not analysed further in the current study, and a thin metallic layer, which is right below the compact ornament and has the shape of a cross. The metallic embroidery is made of metal threads. As the investigation in the optical microscope and SEM revealed, the metal thread (sample MTH1) consists of solid metal strip, made of gilt silver (Ag), wound around a silk core.

As far as the sequins are concerned, the Mitre exhibits three types of sequins, some of which are coloured red. Samples of each of the three types of sequins were taken. The first type (sample S1) has a spherical shape with decoration at the edge. The second type exhibits the same characteristic as the first but there is no decoration on it. Both types consist of silver (Ag) and are constructed by stamping, having a perfectly round shape. The last type of sequin (sample S2) is made by flattening a silver-copper wire, which is evident by the existence of a line crossing the hole and the edge. The existence of the different bright lines on the surface of the sequin indicates that it is gilt and that it was produced with drawing.

By a more detailed observation, a red colour was revealed in sequins S1 and S3. This indicates that the sequins were probably fully covered with a red coating similarly to some other sequins of the object, as evidenced by the naked eye, though no sample was taken from the latter sequins. The red coating was further investigated by FTIR showing the use of silicates and collagenous protein material (possibly gelatine) in conjunction with red ochre (Fe_2O_3) from EDS analysis.

We conclude the presentation of the results concerning the decoration of the Mitre with the examination of sample S4, taken from the top of the Mitre, where the thin metallic ornament is placed. This metallic ornament has a decoration at the edge, made by metal thread. The ornament is made of silver (Ag). The metal wire is made of gold, silver and copper but the presence of the parallel lines on its surface indicates that it was gilt. Furthermore, these lines are the main indication for the manufacturing technique used for the production of the metal wire, by drawing.

Moreover, the intermediate layer of the Mitre is made of paper that is in turn made of cotton and flax fibres, as the analyses showed.

Lastly, the use of adhesive is evident in the entire object. Via a further examination of the relevant samples, the use of, possibly, animal glue was identified on the surface of the fabric. The animal glue is made from the skin bones and tendons of animals, mammals as well as from fish, and had a wide application as an adhesive on textiles (Tímár-Balázsy and Eastop 1998: 119).

6.2 Summary of the suggested conservation treatment

After the thorough investigation of the materials the Mitre is made of as well as the documentation of the degradation signs the Mitre presents, a conservation plan was conducted. More specifically, the mechanical cleaning was recommended for removing the dust and the dirt present on the surface of the object. The existence of insects on the surface and at the lower layers of the Mitre is a problem that must probably be treated with disinfestation, as the vacuuming is not so effective in such cases. Given that, the enclosure of the object in an oxygen free environment was further judged to be necessary. Next, the stabilisation and filling of the missing areas of the fabric were suggested in order to avoid further damages. The use of a dyed silk crepeline in the appropriate colour and fastened with stitches by a thin silk thread was also recommended. The detached metal threads from the embroidery can be secured with the same silk thread. After the conservation treatments, the storage of the object in an appropriate way is suggested. The construction of support with polyethylene foam and a box made of acid-free materials is a good way to provide long-term protection for the Mitre. To conclude, the control of the environmental conditions in the storage is essential. The storage room must be dark, and the relative humidity (RH) and temperature must be stable and range 45 and 55% and 18-20^{o}C respectively.

6.3 Suggestions for future research

Most of the materials the Mitre is made of were examined and identified by means of the lab equipment available at the University of Peloponnese (UOP) in Kalamata and at Technological Educational Institution of Athens (TEI of Athens). I would like to devote this section to some aspects of the study of the Mitre that the present thesis did not touch much upon given the available equipment as well as due to space limitations.

First, I believe that it would be interesting to study and identify the dyes of the textiles, as this would gave us a more complete picture of the textiles used in the construction of the Mitre. Moreover, the use of X-radiography could provide more information about the intermediate layers of the Mitre, the technique of the embroideries, and the way of fastening the decoration, such as the sequins. That way we would have a better representation of the inner structure of the Mitre, resolving all the issues that have left open as far as the construction of the Mitre is concerned. Concerning the conservation treatments, in order to make a more thoughtful study of the suggested disinfestation of the Mitre, it would be wise to further investigate the insects that have infected the object. Lastly, as the case of the Mitre is a “vital” part of it and was not studied in the present thesis, its analysis, especially, the study of the materials it is made of and the identification of its deteriorated parts, would be useful, and together with suggestions about its conservation treatment would, make the study of the Mitre more complete.

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Appendices

Appendix I: Pictures of the objects

Figure 1: Pictures of various aspects of the Mitre of Iosif Androusis

Figure 2: Pictures of various features of the Mitre's case

S1
S2
S3
S4
MTH1
MTH2
F1
F2
F3
F4
F5
F6
A1

Figure 3: The samples obtained from the Mitre

Appendix II: FTIR spectra - Reference samples

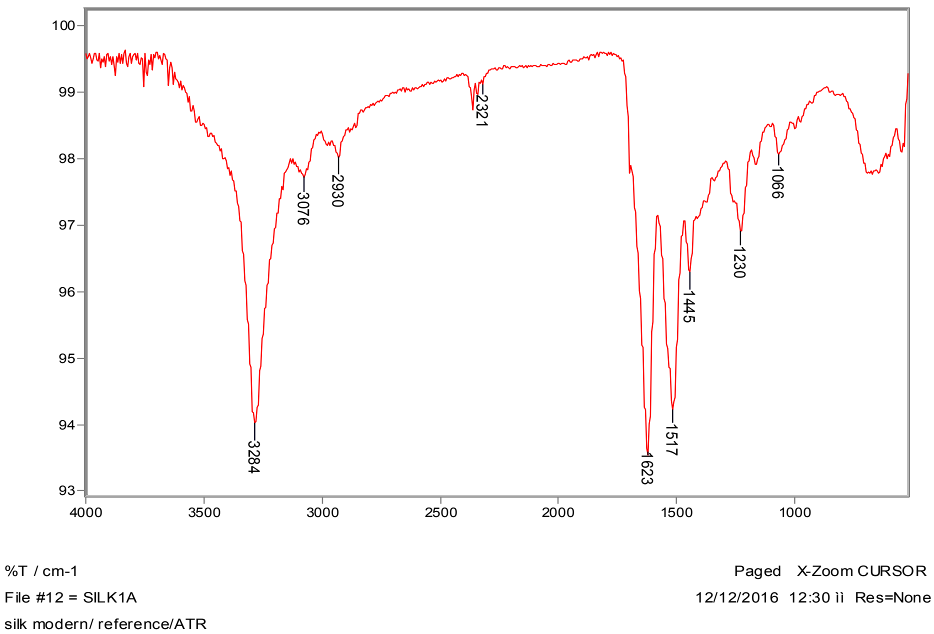

Figure 4: FTIR spectum of Silk textile – Reference sample

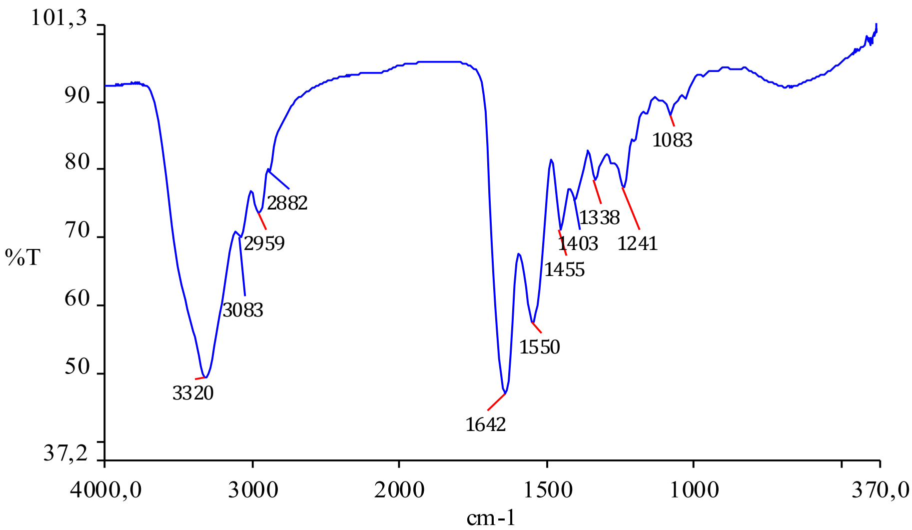

Figure 5: FTIR spectum of Animal glue (rabbit bones glue)– Reference sample