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L'évolution de la broderie de tradition byzantine en
Méditerranée orientale et dans le monde slave
(1200-1800)

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The Use of Metal Threads in the Decoration of Late and Post-Byzantine Embroidered Church Textiles

Abstract: This paper discusses the result of the technical analysis of metal threads used in the decoration of Byzantine and post Byzantine embroidered church textiles. The study of minute samples from embroidered textiles dated between the 14th and the 19th centuries from Greek Institutions gave information about the types of metal threads as well as the manufacturing techniques and the materials used for their production. Only wires and metal strips wound around a silk core (*wound strips*) are recorded in the Byzantine-Greek context from the 14th throughout the 17th century. From then onwards more types such as strips, *tir-tir* threads, sequins (as metal decorative elements) and numerous combined threads are introduced, while wires are used less. The use of these new threads is related to the general stylistic changes that occurred in church embroidery during that time through the influence of Western European and Eastern traditions.

Keywords: Byzantine and post Byzantine embroidered church textiles, manufacturing techniques, metal threads, sequins, *tir-tir* threads

L'emploi des fils métalliques dans la décoration des tissus brodés byzantins et post-byzantins à usage religieux

Résumé : cet article présente le résultat de l'analyse technique des fils métalliques utilisés dans la décoration de broderies byzantines et post-byzantines de textiles à usage religieux. L'étude de petits échantillons de tissus brodés datés du XIV^e au XIX^e siècle par des fondations grecques a fourni des informations sur les types de fils métalliques ainsi que sur les techniques de fabrication et les matériaux utilisés pour les fabriquer. Seuls les fils et les rubans métalliques enroulés autour d'un noyau de soie (filé) sont enregistrés du XIV^e au XVII^e siècle. Ensuite, davantage de genres sont utilisés, tels que des rubans métalliques plats, des fils *tir-tir*, des sequins (éléments métalliques décoratifs)

et de multiples fils composites, tandis que l'utilisation de fils diminue. L'introduction de ces nouveaux fils est liée aux changements stylistiques plus généraux intervenus à l'époque dans la broderie d'or à usage religieux sous l'influence des traditions d'Europe occidentale et orientale.

Mots-clefs : fils métalliques, fils tir-tir, sequins, techniques de fabrication, textiles brodés byzantins et post-byzantins religieux

Η χρήση των μεταλλικών νημάτων στη διακόσμηση Βυζαντινών και μετά-Βυζαντινών κεντητών εκκλησιαστικών υφασμάτων

Περίληψη: Στο άρθρο αυτό παρουσιάζονται τα αποτελέσματα της τεχνικής ανάλυσης μεταλλικών νημάτων που έχουν χρησιμοποιηθεί στην διακόσμηση Βυζαντινών και μετά-Βυζαντινών κεντητών εκκλησιαστικών υφασμάτων. Η μελέτη μικρών δειγμάτων από κεντητά υφάσματα που χρονολογούνται μεταξύ του 14^{ου} και τον 19^ο αιώνα από ελληνικά ιδρύματα έδωσε πληροφορίες σχετικά με τους τύπους των μεταλλικών νημάτων, καθώς και τις τεχνικές κατασκευής και τα υλικά που χρησιμοποιούνται για την παραγωγή τους. Μόνο σύρματα και ελάσματα περιελιγμένα γύρω από έναν μεταξωτό πυρήνα καταγράφονται από τον 14^ο μέχρι τον 17^ο αιώνα. Στη συνέχεια χρησιμοποιούνται περισσότερα είδη, όπως επίπεδα ελάσματα, τριτίρια (tir-tir), πούλιες (διακοσμητικά μεταλλικά στοιχεία) και πολυάρισμα σύνδετα νήματα, ενώ η χρήση των συρμάτων μειώνεται. Η εισαγωγή των νέων αυτών νημάτων σχετίζεται με τις γενικότερες στιλιστικές αλλαγές που επήρθαν εκείνη την εποχή στην εκκλησιαστική χρυσοκεντητική από την επιρροή της Δυτικοευρωπαϊκής και Ανατολικής παράδοσης.

Λέξεις-κλειδιά: Βυζαντινά και μετά-Βυζαντινά κεντητά εκκλησιαστικά υφάσματα, μεταλλικά νήματα, πούλιες, τεχνικές κατασκευής, τριτίρια

The Use of Metal Threads in the Decoration of Late and Post-Byzantine Embroidered Church Textiles

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Introduction

The use of metal threads in the decoration of textiles has a long tradition all over the world. Gleba¹ gives a detailed record about the archaeological finds related to gold threads from the 3rd century BC onwards. These threads have been used with valuable fibers such as silk in weaving, embroidery, tapestry and lace making to produce luxury materials for seculars and religious elites.

In the context of the Orthodox Christian Church ecclesiastical textiles serve both a symbolic and a functional role. They are associated with paradise and the clothes of the angels, so valuable fabrics decorated with precious metals had been considered as the appropriate means to express the glory of God. Most of the ecclesiastical vestments were developed from the secular wardrobe of the early Byzantine period and adopted the hierarchical order followed by the Byzantine court for expressing the different echelons of priesthood.²

Since not many woven Byzantine textiles have survived in Greece, embroidered textiles are used to investigate the changes in the technology of metal thread production as well as their social context between the late and post Byzantine period, as reflected in these materials. Metal thread embroidery, is the technique used continuously from the 13th century onwards to cover the Court's

1. GLEBA, 2008.

2. THEOCHARI, 1986.

and the Church's needs for patterned fabrics, and many examples are found in museums and church collections (Fig. 1).

Various publications about the decorative, symbolic and technical development of church embroidery from the 13th century onwards have contributed to better understand the changes in style, stitching techniques, sources of inspiration and to date more accurately many objects.³ However, although it is relatively easy to identify several of the surface characteristics of metal threads by simply observing them, the investigation of the elements present and the

examination of the manufacturing techniques as well as the determination of the technique employed for the application of the gold or silver layer on the surface of the metal need more detailed analytical investigation.

FIGURE 1. A) STOLE FROM ARKADI MONASTERY DATED TO 1724 AND B) DETAIL OF THE EMBROIDERY. ONE CAN SEE THE VARIOUS EMBROIDERY STITCHES AS WELL AS THE GOLDEN AND SILVER COLORED METAL THREADS. SOME SEQUINS CAN BE ALSO SEEN ON THE RED SILK FABRIC

The image was provided by the Ephorate of Antiquities of Rethymno

3. PAPASTAVROU & FILIOU, 2015; VLACHOPOULOU-KARAMBINA, 1998; THEOHARI, 1986; KORRE-ZOGRAFOU, 1985; JOHNSTONE, 1967; CHATZIMICHALI, 1956.

This paper outlines the results obtained from the analytical investigation of about 300 metal thread samples from Byzantine and post Byzantine embroideries. The basic types of metal threads, as identified in bibliography, will be presented first followed by the brief description of the analytical techniques used for the study of these samples. The morphological characteristics related to the types of threads found, the special features of each type and their use in ecclesiastical church embroidery will be discussed afterwards followed by the technological results related to the manufacturing techniques used for the production of the metal threads and the surface coatings identified. Finally, the quality of the metals used will be discussed in order to confirm the connection with Ottoman textiles.

Types of metal threads

The metal threads are divided in two basic types (Fig. 2a and b), metal strips (either cut from a metal sheet or produced by flattening a wire) and metal wires (mostly drawn⁴).

FIGURE 2. TYPES OF METAL THREADS: A) METAL STRIP, B) PLAITED WIRES, C) GILT ORGANIC STRIPS (AS USED IN WEAVING) AND D) EXAMPLE OF COMBINED THREAD MADE OF A STRIP WOUND AROUND A WHITE SILK YARN WHICH IS FURTHER SPUN WITH A WIRE AND A BLUE SILK YARN.

4. Is the process of producing a wire by passing a metal rod through a series of holes of diminishing diameter in a drawplate or die.

These types have been used for the production of combined threads.⁵ Based on their morphological characteristics the combined threads can be:

- Thin strips of gold or silver wound around a silk or fine linen thread.⁶
- Gold or silver wire which is wound around a fibrous core of a vegetable or animal origin. These spiral wires are also known by the Turkish term *tir-tir*.
- Gilt organic strips. In this case very fine gold sheets are beaten onto an animal membrane, leather or paper, cut into strips and wound around a core yarn, or used flat (Fig. 2c).
- Metal threads of the above types have also been used together to create more elaborate results (Fig. 2d).

The metals mainly used are gold, silver and copper, either alone or combined; while zinc occurred frequently as a component of copper alloys. The fibrous core could be a protein-based fibre such as silk, wool or hair.⁷ Geijer⁸ mentions the use of horse hair as core thread in the Maeseyck tablet woven bands which are dated to the 9th century AD. Alternatively cellulose-based fibres could be used such as linen, cotton or hemp. Since the beginning of the 20th century new materials such as man-made synthetic fibres and aluminium are used.

It becomes obvious that while the types of metal threads have not changed through time, the materials used and their manufacturing techniques have changed a great deal.

Methodology

All samples have been studied using optical microscopy (OM) and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM/EDS) to identify and record the threads type and their morphological characteristics, the manufacturing techniques used for the production of the threads and the metal/alloys composition. Polished cross sections of selected samples have been examined with SEM/EDS and electron probe microanalysis (EPMA) to acquire quantitative information about the metal/alloys, to identify surface coatings, to determine whether the coating layers cover one or both sides

5. JÁRÓ & TÓTH, 1991; INDICTOR & BLAIR, 1990; DARRAH, 1989; GEIJER, 1983; HOKE & PETRASCHKE-HEIM, 1977; GEIJER, 1989 for "horse hair".

6. The term *wound strip* will be used in the text for this type of thread.

7. GLEBA, 2008; SKALS, 1991; JÁRÓ, 1990; BRAUN-RONSDORF, 1961.

8. GEIJER, 1983, p. 96.

of the strips, to measure the thickness of the coating layers as well as the thickness of the strips and the diameter of wires, to identify the organic core threads, and finally to assess the condition of these threads.⁹

Morphological characteristics¹⁰

The morphological investigation has shown that almost all the known types of threads, namely strips and wires as well as combined threads, were used in the Byzantine and post-Byzantine contexts during the period examined.¹¹ Gilt organic strips are the only type that is not found among the Byzantine-Greek samples studied so far.¹² This type of thread is described as an import from the East (Byzantium-Cyprus) that became popular in European contexts between the 11th and the 16th centuries.¹³ However, more recently Jacoby¹⁴ gives new information about the Cypriot metal threads suggesting they belong to the wound strip type and were considered of better quality than Italian (Venetian, Genovese and Milanese) metal threads.

Only wires and wound strips are recorded in the Byzantine-Greek context until the 17th century. Wires are found very often and many objects have been decorated exclusively with them.¹⁵ A shift from wires towards wound strips is seen during the late 17th century when new types of threads and other metal decorative elements are introduced in church embroidery, such as flat metal strips, *tir-tir* threads and sequins¹⁶ as well as the other types of combined threads. However, the wound strip type dominates during the whole period examined.

9. KARATZANI, 2008.

10. For the discussion of the results the data obtained from the study of Western European, Ottoman and Chinese textiles by the author has been used in combination with the literature about the analysis of metal threads.

11. KARATZANI, 2015, 2007.

12. Only one sample has been studied from the author belonging to a woven veil of a Byzantine icon, which most likely has an Eastern origin (KARATZANI & ASENOV, 2015 forthcoming).

13. BRAUN-RONSDORF, 1961; JARÓ, 1990.

14. JACOBY, 2014.

15. Greek authors describe χρυσονήματα (*chrysonimata*-goldthreads) and αργυρονήματα (*argyronimata*-silver threads) refereeing to gold and silver wires.

16. These are either wire coils that have been flattened, or they were cut with a stamp from a metal sheet. In the first case the join of the wire is very characteristic.

Metal strips

The main classification of the wound strips is based on the twist of the strip around the organic core thread, S- or Z-twisted (Fig. 3). Each of these groups is further separated in categories according to the number of coils per millimetre (c/mm) of thread sample, the dimensions of the strips,¹⁷ width and thickness, the diameter of the thread as well as the type and the colour of the organic core.

FIGURE 3. EXAMPLES OF A) S-TWISTED,
AND B) Z-TWISTED WOUND STRIP, (OM X40)

Most of the samples studied are S-twisted with only limited examples of Z-twisted. The bulk of the samples have 2 and 3 coils/mm of sample followed by those with 1 and 4 coils. Samples with more than 5 coils are found as singles examples (Table 1).

TABLE 1: NUMBER OF COILS/MM (WOUND STRIPS)

Coils/mm	1 c/mm	2 c/mm	3 c/mm	4 c/mm	5 c/mm	6 c/mm	Total
S-twisted	11	37	72	16	4	1	141
Z-twisted	-	9	10	1	-	-	20
TOTAL	11	46	82	17	4	1	161

The width of the cut strips ranges between 100 and 500 μm . The samples dated to the earliest period have generally a smaller width (100 and 260 μm); later the width ranges from 200 to 500 μm . The width of the rolled strips varies between 130 and 580 μm , but the majority of the samples have widths between 200 and 400 μm . It is noteworthy that the wider strips are typically found in samples

17. The measurements are given in μm which equals 10^{-6}m , and in nm which equals 10^{-9}m .

having 1 or 2 coils/mm with a few exceptions depending on the closeness of the strip winding around the organic core.¹⁸

The thickness of the strips in this type of threads also presents variations depending on the manufacturing technique and the date (Fig. 4). Cut strips are typically thicker (10 to 21 μm) than those produced by wires. The earliest dated cut strips also show variations in thickness within the same sample. This ranges between 3 and 10 μm for each sample and is possibly related to the production of the sheet by hammering. In the later examples the thickness is more regular, indicating an improved production method for the metal sheet such as rolling. The thickness of the rolled strips is usually between 8 and 17 μm , and they usually have the same thickness throughout the sample.

FIGURE 4. CROSS SECTIONS OF *WOUND STRIPS* (MAG. X400) A) CUT STRIP, AND B) ROLLED STRIP, SHOWING THE DIFFERENCE IN THICKNESS BETWEEN THESE TWO TYPES OF STRIPS

The diameter of the wound strips depends on the thickness of the organic core yarn and on the manufacturing technique used for the production of the strips. In general, it shows some variations because of deformation during the handling of samples or the object itself, so the average of these measurements was used. The diameter of single wound strips is between 120 and 620 μm , but the majority of the samples have a diameter between 200 and 400 μm . The samples that are made of cut strips have a diameter between 150 and 470 μm ; however, those dated to the 14th/15th century have a diameter smaller than 190 μm . The diameter of the threads made from a rolled wire shows greater variability, but usually samples from the same object have similar diameter. Additionally, the diameter of these

18. The number of coils/mm and the width of the strips affect the final appearance of the object since they control the amount of the core yarn that is visible.

threads seems to be also related to the width of the strips, and samples with bigger diameter are typically made with wider strips (Table 2).

TABLE 2: DIMENSIONS OF WOUND STRIPS

Diameter (µm)	Width (µm)	Thickness (µm)	Number of Samples
< 200	130-350	8-27	12
200-300	135-460	7-21	22
300-400	225-350	7-20	11
> 400	250-550	9-23	9
Total			54

Only silk and cotton core yarns have been recorded so far. The colours that have been recorded are white, whitish, yellow and yellowish, as well as brown, orange/reddish and a single example of blue and white yarn. The identification of the colour was done during the study of the samples under the optical microscope. However, it is unclear whether these are the original colours or whether they have been altered through exposure to light. The white and whitish core yarns dominate, followed by the yellow and yellowish. The other colours are found rarely and only after the 16th century.

Wires

Wires are recorded continuously from the 14th/15th to the 19th centuries. All the samples studied, simple wires, *tir-tir* threads and sequins, are drawn. The surface of these threads either bears the characteristic grooves from the draw plate (Fig. 5) or the signs of the rolling process.¹⁹

19. Rolling is a metal forming process in which the metal is passed through one or more pairs of rolls to reduce the thickness and to make it uniform.

FIGURE 5. A) SEM PHOTOMICROGRAPH OF *TIR-TIR* THREAD (MAG. X60);
B) SEM PHOTOMICROGRAPH SHOWING THE LINES INDICATING
DRAWING (MAG. X250)

The diameter of wires ranges from 65 to 130 μm and varies through time, while after the 17th century wires generally become much finer. This difference suggests a change or development in the techniques used for the production of drawn wires, or improvement of the refining techniques of the metal.²⁰

The results have shown that wires were more widely used during the earliest times and there are examples of objects that are decorated exclusively with wires, either gilt or not. According to Theohari²¹ wires are very popular to Byzantine church embroidery and their quality is connected to the number of strands used together, 5 or 7 for the best quality objects and 2 for those of inferior quality.

The diameter of these wires is connected to the number of strands used as well as to the date of the objects. The fineness of the wires is also associated with the type of object; in general objects of small dimensions are decorated with finest threads so as to render better the details of the embroidery.

From the 17th century onwards the use of wires decreases. The increasing use of wound strips, which are typically made from rolled wires, is possibly related to the lower cost of strips in comparison to fine wires²² and the greater flexibility of wound strips.

The *tir-tir* threads are found from the 16th century onwards in two variations. The first is made of wires with round cross section, while the second is made of wires with more rectangular cross section (Fig. 6). Silk yarns have been identified

20. NEWBURY & NOTIS, 2004, p. 35; GLOVER, 1979.

21. THEOCHARI, 1986, p. 34.

22. GLOVER, 1979.

as the cores with a single example of cotton core; the colours used are white, whitish and yellow. The diameter of wires used as *tir-tir* threads ranges from 90 to 145 μm , as in the case of the single wires.

FIGURE 6. EXAMPLES OF *TIR-TIR* THREADS MADE OF A) ROUND WIRE, AND B) SLIGHTLY FLATTENED WIRE. SCALE 5 MM

Technological results

The determination of the manufacturing techniques and the identification of the surface coatings are used for the further classification of the metal thread samples studied. The main objective of the technological investigation is to identify and trace the changes and/or developments that have occurred in these techniques through time.

The main techniques that have been used for the production of wires are hammering, strip or block twisting, strip drawing and wire drawing.²³ Wire drawing is recording since the 8th century AD.²⁴ Strips could have been made by cutting them from a metal sheet, gilt on one side or not, or by flattening a wire, typically drawn, which could also be gilt.²⁵ Furthermore, a metal sheet from the earliest periods would be hammered, but later it could have also been produced by rolling.

Strips

The indications for the manufacturing technique used for the production of solid metal strips are the presence of gold on the external surface only (cut strips) or on all sides of the strip (from gilt wire) and the micromorphology of the strip edges

23. HAWTHORNE & SMITH, 1979, p. 87; ODDY, 1977, 2004.

24. ARMBRUSTER, 2005.

25. JARÓ & TÓTH, 1991; JARÓ, 1990; HAWTHORNE & SMITH, 1979, p. 156; SMITH & GNUDI, 1959, p. 381-382.

showing the cutting marks or rounded edges, respectively (Fig. 7). Furthermore, the cut strips occasionally have irregular width and variable thickness, while rolled strips have more regular width along their length.

FIGURE 7. PHOTOMICROGRAPHS OF *CUT* AND *ROLLED* METAL STRIPS.
A) S-TWISTED *WOUND STRIP* WITH SILK CORE; B) PHOTOMICROGRAPH OF
THE STRIP EDGES SHOWING THE CUTTING MARKS (X3,300); C) S-TWISTED
WOUND STRIP WITH SILK CORE, AND D) PHOTOMICROGRAPH SHOWING
THE ROUNDED EDGES OF THE STRIP (X450)

The study of cross sectioned samples is by far the more accurate method to determine the presence of gold; however, it could not be used for every sample.²⁶ The surface study with SEM-EDS supplemented the cross-section data, since it is possible to open the strips and investigate the inner surface as well. The identification of cutting marks on the edges of the strips and the presence of signs from the flattening process were also taken into account.

26. Sample preparation time and costs of the analytical investigation were two crucial issues for not apply this technique to every sample.

Fifty-three cross sections of metal strips have been studied covering all the periods examined. Twenty-seven strips are gilt on all sides indicating the flattening of a gilt wire for their production. These strips generally have a very even thickness along their cross section.

The earliest strips that have been produced by flattening a gilt wire are dated to the 16th century and this technique is used from then onwards.²⁷ The two earliest samples are wound strips and belong to a codex that was made at the Imperial workshops of Constantinople for the Empress Anna Palaeologina who died in AD 1365; however, the codex has been rebound during the 16th century.²⁸ The first sample belongs to the end band and the other comes from velvet fabric used as cover for the codex. Both samples show the characteristic parallel lines at their surface, but the sample interwoven in the velvet fabric bears some controversial characteristics which are more typical of cut strips. This suggests a different production technique and possibly a different origin and date for the woven fabric. The velvet fabric is possibly a recycled piece with Ottoman origin.

Eight samples of strips that are gilt on one side were found, suggesting the use of a gilt metal sheet for their production. The samples belong to ecclesiastical textiles and are dated from the 14th century onwards. Only three of these strips show variations in their thickness by 3 to 6 µm, but all of them show cutting signs on their edges. However, parallel lines are observed on the surface of samples dated after the 17th century, indicating that the sheet was produced by rolling. From the 18th century onwards, all the samples have an even thickness along their cross section. This provides further evidence for the use of rollers for the production of the metal sheet. It is important to note that this type of cut thread is still used during the 19th century.

Among the 19 strips that are not gilt only four show clearly that they were cut from a metal sheet. Moreover, two of them belong to an object where strips gilt on one side were used. The remaining 15 examples typically have a very even thickness along their width, but in many cases the marks on their edges are not very clear making it difficult to decide about the manufacturing technique used.

Wires

All the wires studied show the characteristic grooves on their surface indicating that they were drawn. Additionally, most of their polished cross sections show an

27. Unfortunately, not many samples from earlier periods were obtained in order to examine the presence of such strips.

28. Personal communication with Dr G. Boudalis the conservator of the codex, who also provided the samples.

almost perfectly circular circumference, further confirming that they are drawn. The earliest examples are dated to the late 14th/15th century, suggesting that drawn wires fine enough (diameter of about 100 µm) to be used as metal threads were available. The same characteristics are present on the surface of all *tir-tir* threads studied.

Interestingly the data obtained confirmed that samples used in the decoration of a single object were produced with the same technique. The wires are all drawn and the strips are either all cut from a metal sheet or have all been produced by flattening a wire. These threads can be gilt or not.

The results show that the strips made by flattening wires dominate in comparison with the cut strips. It appears, however, that rolled strips never replaced completely the cut strips. Cut strips are found throughout the period examined in a smaller scale, suggesting that some workshops preferred to use the old technique for the production of metal threads. This preference is either related to the availability of raw materials and especially gold or to the cost of fine-drawn wires. According to Dieter,²⁹ the reduction per pass from the draw plate is between 15 to 25 %, so for producing such wires at least 10 passes would be needed. Moreover, very well refined metals could only be used to avoid breaking.

Surface coatings

Three types of surface coatings have been detected, gilding on silver threads, silvering and gilding on copper threads as well as a coating of zinc on copper threads producing a brass surface. Gilding is recorded from the 14th century onwards and used during the whole period examined. It is found on all types of threads covering one or all sides of the strips (Fig. 8). Some rare examples of gilt brass threads and copper threads that were first silvered and then gilt have been also recorded. Four examples of copper threads that were covered with a layer of silver were also detected; these were either an imitation of silver-based threads or were covered with a layer of gold that is worn off.

29. DIETER, 1961, p. 534.

FIGURE 8. SEM MICROGRAPHS THROUGH A) THE CROSS SECTION OF A GILT CUT STRIP, B) DETAIL OF THE GOLD LAYER WHICH COVERS ONLY THE EXTERNAL SURFACE OF THE SILVER STRIP; C) CROSS SECTION OF ROLLED GILT STRIP, D) DETAIL OF THE STRIP EDGES SHOWING THE GOLD LAYER

The gold layer is always very fine, often irregular and generally covered with silver and/or copper corrosion products. The measurements were taken at the areas with the thickest layer because it was assumed that this was the original thickness. In general, it was found that the differences in the thickness of the gold layer are related to the type of thread (Fig. 9).

FIGURE 9. A) CROSS SECTION THROUGH A GILT WIRE,
B) DETAIL SHOWING THE MAXIMUM
THICKNESS OF THE GOLD LAYER

Gilding is normally much thicker on the surface of wires and on *tir-tir* threads (1.5-2.5 μm) than on the strips. In the case of the wound strips there is no variation between rolled and cut strips (400-900 nm). The flat strips typically have much thicker gilding (850 nm-2000 nm). The thickness of the silver layer varies between 450 nm and 2500 nm. The zinc-rich surfaces are found in the 19th century and are only found on copper threads, creating a layer of brass at their surface. Nine examples were found, belonging to almost all types of threads. The thickness of the brass coating is between 3000 and 5000 nm (Fig. 10).

FIGURE 10. DETAIL OF THE CROSS SECTION THROUGH A BRASS COATED
THREAD, A) SEM PHOTOMICROGRAPH OF THE SAMPLE;
B) AND C) X-RAY MAPS SHOWING THE DISTRIBUTION
OF COPPER AND ZINC ON THE SAMPLE, RESPECTIVELY

Interestingly, among the 300 Byzantine/Greek samples studied so far no solid gold threads have been found. The only examples analyzed by the author come from Chinese and Western European secular textiles dated to the 9th and the 13th centuries, respectively suggesting that the cost of gold was too high to be used for this purpose during this period.³⁰

Various techniques could have been used for applying the gold layer on the surface of the metal sheet or the rod used for wire drawing. The most appropriate would have been diffusion bonding, amalgam or fire gilding and finally, the application of a gold leaf with the help of an adhesive.

Diffusion bonding refers to the application of the gold leaf by burnishing it directly onto the surface of the metal and then heating the object gently for a very short period until an inter-diffusion with the underlying metal occurs.³¹ This technique was in practice since 1200 BC and has been identified mostly on silver or copper objects.³²

In fire gilding, gold is dissolved in mercury and the mixture produced (gold amalgam) is rubbed onto a clean metal surface, usually silver or copper. The object is then heated until most of the mercury has evaporated, leaving behind a continuous and firmly bonded layer of gold. The advantages of this technique include the ability to apply a very thin layer of gold and the possibility of repeating the process so as to build up a thicker layer of gold.³³

Leaf gilding relies on applying the gold leaf on the surface of the silver or copper with the help of an adhesive such as egg white because gold leaf is extremely fine and difficult to handle (leaf is < 1 µm).³⁴

Mercury was not detected during the analysis of the samples³⁵ and even in high magnifications the interface between silver and gold did not show characteristics of fire gilding. Gold leaf was identified in a small number of samples studied and diffusion bonding is the only other technique that could have been used.³⁶

Silvering has been used as a surface coating on metals such as copper, bronze and brass. The history of silvering is as long as the use of silver metal although

30. KARATZANI, REHREN & ZHIYONG, 2009; KARATZANI, 2007.

31. LA NIECE & MEEKS, 2000, p. 232; ODDY, 1993, p. 176.

32. ODDY *et al.*, 1981.

33. ODDY, 2000, p. 5.

34. RACKHAM, 1968, p. 51.

35. Mercury is very volatile, so it is not easily detected.

36. KARATZANI, 2007.

silver plating is not as commonly found as gilding. The basic methods used for the application of silver coating are similar to those used for gold.³⁷

The use of zinc for the production of brass has also a long history.³⁸ The term *aurichalcum* was used for brass throughout the medieval period. Theophilus describes brass making during the 12th century).³⁹ The method, cementation process, involves the heating of copper with zinc carbonates and silicates called *calamine* so that copper absorbs zinc, thus avoiding loss of zinc which has a lower boiling point.⁴⁰ According to the same author the resulted alloy contains about 28 % zinc and has a golden color.

From the 18th century onwards, also solid copper could be *brassed*, by exposing it to zinc fumes. The brassed copper technique has been used since the first half of the 18th century in Lyon for making gold-coloured wires which were also used for the decoration of textiles.⁴¹

Metal analysis

Metals with two different compositions were used for the production of different types of threads. Silver-copper alloys were detected in the strips that were cut from a metal sheet. Pure or almost pure silver was used for the production of drawn wires and other threads made of wires such as *tir-tir* threads and rolled strips, as well as sequins. Silver-based threads are typically associated with silk core yarns, while the copper-based threads examined are only twisted around yellow cotton yarns.

The majority of the samples analysed are made of almost pure silver and are gilt. The same pattern is recorded in the samples with Ottoman origin, while the Western European samples are usually made of silver-copper alloys, and are not generally gilt. After the 18th century non-gilt threads are frequently found and during the same time the copper-based threads are introduced also to the Greek milieu.

Finally, it was found that gilt and not gilt threads used for the decoration of the same object usually have the same elemental composition, suggesting the same source for the two kinds of threads.

37. LA NIECE, 1990 and 1993.

38. HOOVER & HOOVER, 1950, p. 408.

39. HAWTHORNE & SMITH, 1979, p. 143-145.

40. SCOTT, 1991, p. 19.

41. JÁRÓ, 2003, p. 35-36.

Conclusions

Through the study of various metal thread samples, it was possible to determine the morphological and technological characteristics of the metal threads used in church embroidery from the 14th century onwards. At the earliest times mostly wires are used, from the 17th century onwards new types are introduced similar with those used in Western European and Ottoman textiles. However, some fundamental differences have been recorded. The most striking one is the use of drawn wires and rolled strips in the Byzantine/Greek and Ottoman contexts versus cut strips found in the Western European objects, suggesting a different source for the metal threads. It is noteworthy that the use of drawn wire that early period can be used as indication for the high quality of these threads. Since the cost of wires doubled with every five reductions in the draw plate, the fine wires used for embroidery and weaving, which have a diameter between 80 and 100 μm , would be very expensive. Another difference is the use of gilt threads in Byzantine/Greek and Ottoman objects versus the silver and copper-based threads without surface coatings in Western European samples. However, most of the Western European samples belonged to secular objects, so it is likely that the cost of gilt threads would be too high for such objects. In the contrary, most of the church embroideries were commissioned by wealthy patrons and materials of the best quality would be the appropriate mean for their decoration.

Unfortunately, it was not possible to study objects and samples from the same embroidery workshops in order to examine the consistency of the materials used through time, but through this research it became clear that the samples from the same object, gilt or not, had the same quality and the same morphological characteristics suggesting that the threads were bought from the same source. It is reasonable to assume that the types of threads used and the quantities of each type required for an object would have been calculated and possibly obtained in advance. Metal threads would be expensive to acquire, so it is unlikely that embroidery workshops would have big stocks of them. Moreover, since ecclesiastical textiles were very often commissioned an estimation of the final cost would have been required. The acquisition at once of all the stock of threads needed has also some practical advantages since it would prevent any change in the special characteristics or appearance of the threads used on the object. Until the 18th century the manufacturing of metal threads was performed manually. Even though a high specialization is required for such a craft, minor differences would occur between every stock produced. This applies to the metals used and consequently to the colour and to the thickness of the threads.

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