The laser technology and its applications in the copper metal embroidery threads cleaning and treatment field – Analytical experimental study

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1. Abstract:

The great development Encouraged the use of laser applications for the treatment and restoration of the copper metal threads embroidery textiles with safety technology without the use of any chemicals or solutions so we select this experimental study as the modern applications of laser science techniques in the field of treatment and conservation of archaeological textile embroidered with metal thread has been proved to be an effective way to extend the life of the object and improve its surface and visual properties. Has become an urgent necessity because of the difficulty of the case of these acquisitions of the unique nature of the decorative composition and physical appearance, in addition to the many sources to access the laser beam and its high efficiency in the cleaning of metals in general and also proved that many disadvantage of the traditional cleaning methods, whether mechanical or chemical, and do not fit with the special collection of metal threads embroidered textiles, Therefore, the study was carried out by emphasizing the scientific and technical coordination between the textile conservators and the laser science specialist to choose the best types of laser and its suitability with the object case and how to control the operating conditions with the general deterioration condition and other organic components materials during and after cleaning and the use of laser technology seemed to be the optimal study to achieve the desired goal with it could become one of the most useful studies for conservators in the field of treatment and restoration of textiles embroidered with copper, gilded or silver metal threads Study showed many results that were discussed and interpreted scientifically by examination and scientific analysis for The laser technology, which seemed to be the optimal study to reach the desired goal with a view on the compatibility with our holdings in order to preserve our heritage , which is an open book of history because it contains a wealth of information about our culture ,history and technique .

Keywords:

Laser, cleaning, threads, Metal, Corrosion

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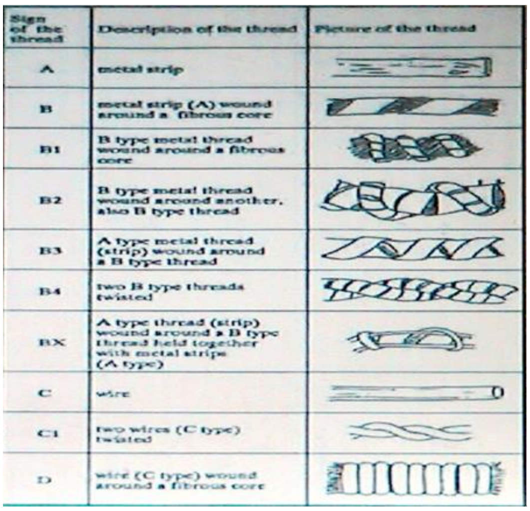
Introduction

The study examined the types and classifications of metallic embroidery threads, while highlighting traditional techniques for cleaning copper metallic threads and their most important flaws, while showing the great development in the field of using lasers and its applications to clean and treat antiquities in general in a safe manner. Which was shown by many previous studies where Jaro confirmed (11) after his experience in cleaning textile embroidered with metallic threads by traditional methods, this treatment must be carried out in the minimal limits with extreme care and accuracy, as it may cause the metal thread to be damaged and rusted in the future. Cooper (4) suggested the idea of spraying the surfaces of the metal embroidery threads with water before performing the cleaning process using laser in helium atmosphere to reduce the effect of high temperature on the surface of the metal, and (8) Fotakis's study showed the importance of examination and analysis to follow up the success of the laser technology in removing corrosion layers and calcifications of metallic threads, as Abdel Karim (1) used the laser beam technology for cleaning Egyptian textiles embroidered with metallic threads and evaluated its use. (28) Scibe presented a detailed presentation of metallic threads shapes and their industry technique used in Islamic textiles in the Middle Ages, Raditoiu et al. (24) also helped in presenting the FTIR method as an effective method for analyzing the inner fibrous core threads of metallic embroidery threads, this research was presented in details through the four study steps of the research and description of the samples used, type of device and its specifications and operating conditions for each experiment with explanation and discussion of results from During the presentation of the analysis and examinations that were done before and after conducting the experiments, finally the findings of the research were mentioned by clarifying the advantages and disadvantages about using applications of laser cleaning technology.

2.Materials and methods:

2.1. Types and categories of embroidery threads

The manuscript of Saint-Aubin's Art of the Embroidery considered as one of the most important manuscripts, including the old industrial methods of embroidery thread [12] and the most important types and classifications as shown in figure (1) and the attached table.



Sign of the thread	Description of the thread	Picture of the thread
A	metal strip	
B	metal strip (A) wound around a fibrous core	
B1	B type metal thread wound around a fibrous core	
B2	B type metal thread wound around another, also B type thread	
B3	A type metal thread (strip) wound around a B type thread	
B4	two B type threads twisted	
BX	A type thread (strip) wound around a B type thread held together with metal strips (A type)	
C	wire	
C1	two wires (C type) twisted	
D	wire (C type) wound around a fibrous core	

two (B) type threads twisted	B4	Metal strip	A
(A) type thread (strip) wound around a (B) type thread held together with a metal strips (A type)	BX	Metal strip (A) wound around a fibrous core	B
wire	C	(B) type metal thread wound around a fibrous core	B1
two wires (C type) twisted	C1	(B) type metal thread wound around also (B) type thread	B2
wire (C type) wound around a fibrous core	D	(A) type metal thread (strip) wound around a (B) type thread	B3

Fig (1)

Which has confirmed the manufacturing technology development over the different historical eras and this has included the four main types of embroidery threads as follows:

2.1.1. Spiral metal threads:

These are yarns made of flat metal strips wrapped around themselves in spiral or helical form, a kind of non-woven metal embroidery thread with a non-fibrous interior [18] as shown in figure (2) the thread which are either very thin are called Purl or thick are called Cantilles, and the spiral embroidery threads are installed with a special technique that uses silk fixing filament treated with beeswax through the metal threads for installing them on the surface of textiles ([28].

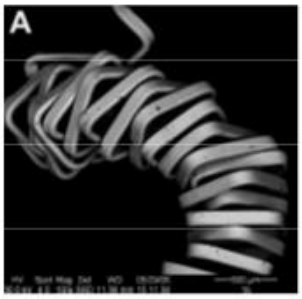


Fig (2)

2.1.2. Soumak Threads:

These are the metallic golden or silvered ornamented copper embroidery threads, which are known in Turkish as Soumak or Simkes, that means; the metal wire or strip wrapped around an inner fibrous core from cotton, linen or silk yarn spinning or not being spun as in figure (3) or Animal Membrane [17] ,which commonly used in Cyprus from the 11th century or wool and animal hair, soumak threads has been widely used in the middle east embroidery during Ottoman administration [34].

Fig (3)

2.1.3. Tumbag Threads:

The name of these threads is traced back to the Tumbago alloy which used by the Indians and transported by Muslims, this alloy consisting of 50% copper, 33% gold, 12% silver, inherited by the Ottoman embroiderers in Istanbul from their ancestral Seljuqs of Anatolia [10].

2.1.4. Al-Mukhaish Threads:

Al-Mukhaish is a kind of high-quality thin embroidery threads that is pulled and manufactured from copper threads coated or plated with silver, which is known as the white **Al-Mukhaish Threads knot** , which is famous for its embroidery of the Holy Kaaba covers and hangings [37] as shown in figure (4) , it was also used for embroidery of governors' formal clothes, khedive and princes in the era of Muhammad Ali pasha 's family in Egypt [36], it was also used in the Yellow **Al-Mukhaish Threads knot**, which was made of silver wire coated or plated with pure gold as shown in the figure (5), which was manufactured by the winding wheel manual method [33].

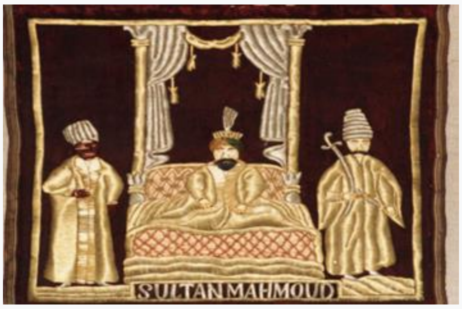


fig (4)

fig (5)

2.2. Traditional techniques for cleaning metal embroidery threads, and the most important disadvantages:

There were many traditional methods of mechanical and chemical methods for cleaning metal embroidery threads, but they proved to be inconsistent with the special nature of the embroidery thread [26]. This prompted us to carry out this experimental study.

2.2.1. Mechanical cleaning using hand tools:

Mechanical cleaning using brushes, either rough fiber glass brushes or ordinary brushes , the scalpels with the curved or the sharp thin blade [6] , different shapes of spatulas and bamboo sticks, by following the light scratching method to dismantle the corrosion layers and remove them , but this method is not proportional to the nature of the metal threads surface due to the presence of protrusions, highs and lows that increase the overlap of the corrosion particles between the layers of the metal embroidery threads and the fabric below them. This method may also destroy the coating layer if they exist [11], may also cut and tear the embroidery threads and other components with the difficulty of cleaning waste disposal, which will interfere with fibers piles and textile fabrics [18].

2.2.2. Cleaning using polishing and refinement materials:

This method is followed with metal embroidery threads with thin and fragile layers corrosion, either using polishing and refinement chemical materials from magnesium carbonate or calcium bicarbonate mixed with some waxes or some traditional old methods by using natural organic materials such as flour, bran, oil, yeast or free bread crumbs as to avoid the biological infection which can destroy all organic components in the embroidered textiles [2] , however; this method was considered one of the worst cleaning methods where the materials deposition overlaps between the embroidery components and corruption of the general shape with the disposal impossibility of the sedimenting residues [29].

2.2.3. Milling machine cleaning:

This method was followed in British and American Museums [35], by using fine granular silicate polishing materials at the low degree of shooting and at an appropriate distance. However, this method can not be used in the case of large embroideries because the cleaning process is limited to the area of the cleaning box and this method can cause the destruction of the textile and fillings under embroidery threads, and may tear and cut the embroidery parts, with the disposing difficulty of the cleaning waste and overlapping with the embroidery fibers and textile piles [18].

2.2.4. Chemical cleaning of embroidery metal threads:

Many materials are used; like some organic solvents such as methanol or Perchlorethylene with some [30] Nonionic Surfactant, or using some acidic solutions such as Formic acid to remove the corrosion layers of embroidery copper threads or using some alkaline solutions such as ammonium hydroxide to remove products corrosion of copper and silver embroidery threads, either by the normal application methods or using the poultice method with paper pulp saturated with the cleaning material [1] However, one of the main disadvantages of this method is the chemicals residues deposition and the formation of new corrosion compounds layers on the embroidery threads surface with high acidity, causing the fading of the textile dyes and the destruction of internal embroidery fillings and other components[11] .

2.3. Reasons for choosing laser cleaning technology:

many reasons that encouraged the study to investigate this modern field, discover its secrets and evaluate its validity with the metal copper threads embroidered textiles which are very complex and specific as the following:

2.3.1. Most of the traditional methods are considered illogical application methods and do not give successful results to clean the metal embroidery threads as mentioned above [15]

2.3.2. The use of laser technology has been succeeded as a modern method [16] and gave useful results on many samples and experimental replicas. Therefore, the results and compatibility of these experiments should be evaluated on our objects and museums conditions

2.3.3. Laser sources are multiple among gas laser, liquid lasers, solid materials laser, dyes laser, etc. to produce laser beams with different wavelengths such as Excimer Laser that has lighting chemical nature in ultraviolet range of 266 nanometers wavelengths [31], Second Harmony YAG in optical range 532 nm wavelength and laser Nd: YAG that has a thermo-mechanical lighting chemical laser in the infrared range at 1064 nm [4] which is used in the research of our Experimental study.

2.3.4. Flexibility, ease of use, operating conditions selection and easy control of the laser beam according to the embroidered textile object condition that we need to treat and clean. So [5] the dynamic laser cleaning process has been transform from being a process for removing stains, calcifications and corrosion layers to become the effect treatment process and a mean to prolong the object age and improve its morphological and visual properties [23].

2.4. Steps of the experimental study of laser cleaning:

The study is benefiting from the modern laser applications to remove dirt and corrosion layers from copper metal threads through four experiments, by using of Nd: YAG laser at 1064nm wavelength, which the international study has proven its efficiency and effectiveness [4] with corrosion layers components, so we have changed different procedures per experiment to achieve the best conditions and results, and evaluation the procedures and the experiment results through the investigation and scientific analysis for understanding the cleaning and removal mechanisms ,examine all materials and discuss every details.

2.4.1. Samples used in the study:

According to Reponen advice that it is impossible to cut parts of the archaeological textiles for using as experimental samples and It is also unreasonable to apply any new method of treatment directly on the archaeological textiles. In addition, it is illogical that experimental studies should be carried out on artificial samples that were prepared under ideal conditions, controlled and non-conformity with the case of the required object, in addition to the difficulty of getting the embroidery metal threads implemented with the same ancient raw materials and techniques because the copper metal embroidery threads are old manufacturing and the extinction of this art in Egypt, so the researcher used old samples from embroidered hanging with copper metal threads it is 90 years

Fig (6)

old, as in Figure (6) , which is owned by the researcher and similar to the old objects regarding the raw materials , components ,industrial techniques and deterioration aspects .

2.4.2. Type of laser machine used in the study:

The experiments were implemented in the National Laser Institute at Cairo University and we worked on Q-switched Nd: YAG laser, Continuum Sure lite II, was made in USA in 1994 as in figure (7). It is one of the types of laser solid-materials that produced from a Yttrium Aluminum-Garnet crystal covered with a rare earth element known as Neodymium This type of laser produces laser beam from the infrared sector at the range of 1064 nm wavelength, which are invisible rays and the device was supplied with Q Switch to reduce pulse time and increase the power, with the possibility of determining the time that was taken per pulse [38] as needed and helped to Give us low- Intensity laser to clean sensitive surfaces.

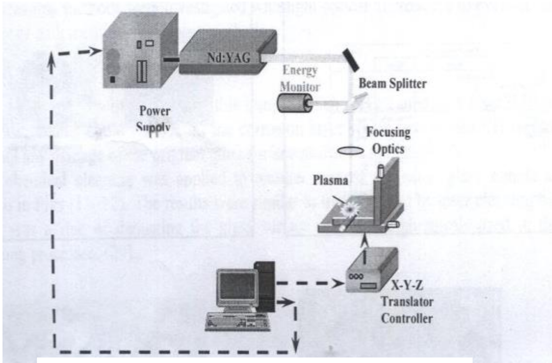


Fig (7)

2.4.3. The Study Experiments:

the study in four experiments implemented through four samples of copper- metal threads embroidery textile where the operating conditions have been changed at each experiment to achieve the best results as follows:

2.4.3.1. The first experiment:

This experiment was based on the evidence presented in some scientific references, that the use of the YG laser beam with a density of 6.6: 9.8 J / cm 2 at 1064nm wavelength was effective in removing copper rust compounds for metallic embroidery threads. [14] The experiment was completed using a lens Spherical Concentration of the Falling Radiation Sequentially in an area of 0.5mm to increase the control of the beam used while minimizing its effect on the inner pulp of the embroidery thread and the other components of the textile objects.

The wavelength of the laser pulses	1064nm
The distance between the sample and the lens	8.5 cm
Power of the used beam	150 mj / pulse
Average frequency	10 Hz
Intensity of beam (magnitude)	8.66 J / cm^2

Table No. (1) shows The operating conditions in the first experiment

2.4.3.2. Second experiment:

The experiment was completed using a quartz cylindrical lens to obtain a linear laser beam corresponding to the technical construction of the metal embroidery thread to facilitate the cleaning process using successive shoots. [13] The beam energy in this experiment was reduced from that in the first experiment.

The wavelength of the laser pulses	1064nm
The distance between the sample and the lens	8 cm
Power of the used beam	17 mj / pulse
Average frequency	2 Hz
Intensity of beam (magnitude)	4.6 J / cm^2

Table No. (2) shows The operating conditions in the second experiment

2.4.3.3. Third experiment:

Based on the scientific evidence that the low-energy laser beam <1 J / cm2 is safer on the components of the embroidered fabric as its contents of metal fibers with inner fiber core underneath its cardboard fillings [1], and the effects are scaled either thermally or mechanically [8]. Control Panel and also to change the distance between the sample and the lens, taking into account the compatibility between the number of the used laser pulses and the wavelength of the laser beam, the duration of the cleaning process and the frequency of this Beam, with the use of a quartz spherical lens to obtain a linear laser beam and improve the performance of the cleaning process [31] by giving 30 Shots / min.

The wavelength of the laser pulses	1064nm
The distance between the sample and the lens	5.2 cm
Power of the used beam	11 mj/ pulse
Average frequency	10 Hz
Intensity of beam (magnitude)	0.35 J / cm ^{2}

Table No. (3) shows The operating conditions in the third experiment

2.4.3.4. Fourth experiment:

The sample used for this experiment differed from the rest of the samples in the previous three experiments because it was the same of the completely damaged metal threads that suffer from loosening and fragility. This is to determine the success of the laser beam in achieving the cleaning process with these cases without further damage to the sample using low beam density to give 30 shots concentrated in these places of damage.

The wavelength of the laser pulses	1064nm
The distance between the sample and the lens	5 cm
Power of the used beam	40 mj / pulse
Average frequency	5 Hz
Intensity of beam (magnitude)	5.43 J / cm ^{2}

Table No. (4) shows The operating conditions in the fourth experiment

3. Results and discussions:

The samples were examined before and after the experiments using modern devices and the results were as follows:

3.1. Stereo Microscope investigation results

We used A German Microscope –made by Zeiss model 2004 at the investigation and analysis lab. of the National Center of Fine Arts, the results were as follows:

3.1.1. The investigation and imaging result of the first experiment:

The sample was investigated before the experiment with 16 x magnification as shown in Figure (8) which showed the deterioration and damage of the embroidery threads in some parts with the appearance of different corrosion layers. The sample was also investigated after being experimented with 40 x magnification as shown in Figure (9), which showed the complete removal of all layers of corrosion with the appearance of a clear luster on the metal threads surface by the use of the spherical lens, which worked to focus the high energy laser beam.

Fig (8)

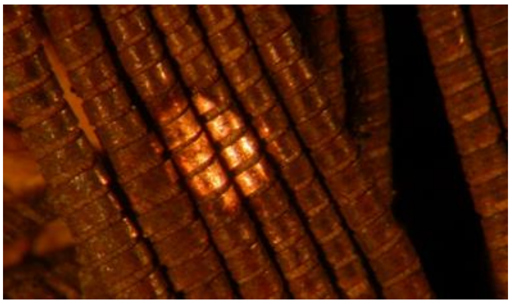


Fig (9)

3.1. 2.. The investigation and imaging result of the second experiment:

The sample was investigated before being experimented with 40 x magnification as shown in Figure (10), which showed the state of decomposition, erosion and corrosion with missing parts in the metal embroidery threads, in addition to a thick layer of green corrosion, copper carbonate mixed with other corrosion products of cuprite and tenorite. The sample was also investigated after the experiment with 40 x magnification as shown in Figure. (11), which showed the removal of most of the green corrosion thick layer, and the surface of the metal threads became more homogeneous. However, the internal fibrous core, which is still saturated with green color copper corrosion, whereas the cleaning process has been done concentrated on the metal Surface only and did not deepen to the inside, which confirms the good control degree during the operation.

Fig (10)

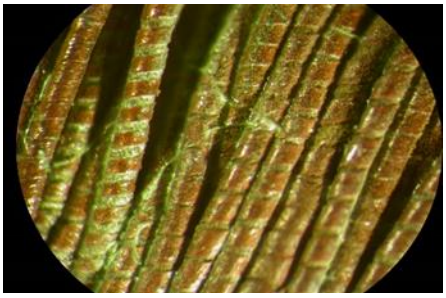


Fig (11)

3.1.3. The investigation and images of the result of the third experiment:

The sample was investigated before being experimented with 16x magnification as shown in Figure (12), which showed the general condition of the metal embroidery threads with loosening, weakness, accumulation of dust, and remains of tacking stitch threads. The sample was also investigated after the experiment with 40 x magnification as shown in Figure (13), which showed the improvement of the metal threads surface appearance and the removal of the corrosion products with preserving the original patina color as a conclusive evidence of the experiment success.

Fig (12)

Fig (13)

3.1.4. The investigation and images of the result of the fourth experiment:

The sample was investigated before the experiment with x 16 magnification as shown in Figure (14), which showed the state of deterioration and degradation in the metal thread and fibrous core with its hardening and staining (16), The sample was also investigated after the experiment with x 60 magnification as shown in Figure(15) which showed the effect of concentrated focusing laser pulses, the black spots presence on the metal threads surface is a proof that the cleaning process did not achieve the required success because the metal threads were suffering from erosion ,fragmentation and disintegration..

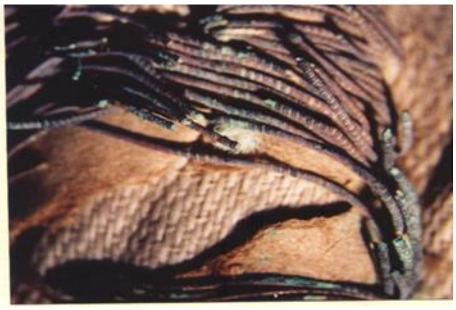


Fig (14)

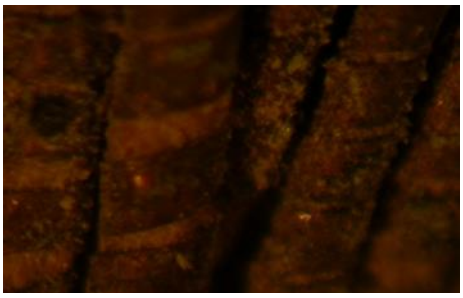


Fig (15)

3.2. Results of sample analysis using FTIR Fourier; transforming Infra-Red

The samples were investigated by The Jasco FT / IR 430 model 2002 that was made in Japan, in the geophysical research lab. at the National Research Center in Cairo for qualitative analysis and identification of function groups [24] for both the internal fibrous core and the embroidery bottom cardboard filling as follows:

3.2.1. The analysis result of the embroidery metal thread internal fibrous core:

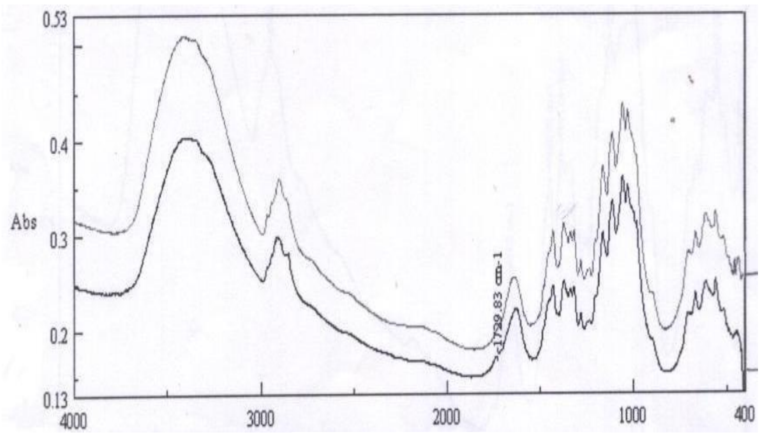


Fig (16)

The results of the sample analysis were compared to various standard samples of linen, silk and cotton fibers to identify the type of the embroidery metal thread and the internal fibrous core, which The analysis proved that it conformed with the result of the Egyptian cotton fibers as in Figure(16) and definition of cellulose degradation according to function groups, identification through absorption peaks [3] as shown in table (1) specially absorption peaks in the range between 1000: 2000nm which Called the fingerprint area and the appearance of the carbonyl group{ C = O} as an indicator for The decreasing and breaking of cellulose particles Polymerization degree into short and weak chains at the Wave number 1729.

Wave number [cm-1]	Peak characteristics	
3409.53	OH-	stretching inter molecular H-bending hydroxyl group.
2900.41	C-H	stretching for Aliphatic group.
1729.83	C=O	Stretching(carbonyl group)
1635.34		Adsorbed H_2O
1430.92	C-H	Bending over lapping OH bending
1373.07	C-H	Bending "symmetric" for CH_3
1282.15	C-H	Bending "very weak"
1112.73	C-OH	Stretching
1058.73	R-CH2-OH preliminary alcohol	
1031.73	C-O	Stretching
667.25	C-H	Bending (non saturated compounds)
615.181	C_1-O-C_4	B glucosidal bond
561.184	C=O	Bending

Table No. (5) shows function groups identification through the embroidery metal thread internal fibrous core absorption peaks

3.2.2. The analysis result of the embroidery metal thread bottom with cardboard filling

This analysis has identified the cardboard sample and its manufacturing technique and additives , the result is identical to the modern cardboard sample made of grounded mechanized wood pulp, as shown in Figure (17), which contains high percentage of lignin, which its function groups have been showed as methoxyl group [OCH3], which includes both alcohols, phenols and ethers, as in Table (2) Which appear in the Stretching frequency of the O-H in the Wave number between 2500: 3696 and the bending frequency C-O-H in the Wave number between 1000: 1500 in addition; the cardboard was containing the aromatic aldehydes and aliphatic aldehydes that appear in the 1716.34 rang

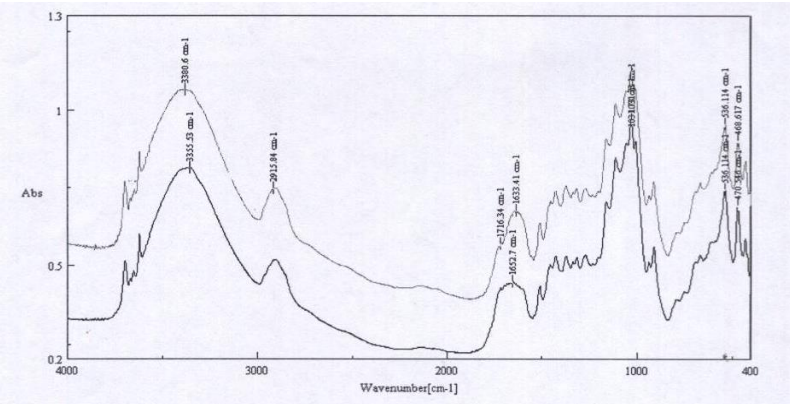


Fig (17)

As evidence of partial oxidation in the filling cardboard. the Starch as an additive during manufacturing at 3619 was also identified, in addition to the appearance of the rosin as polishing and bonding materials (27) in the 912 range.

Wave number [cm-1]	Peak characteristics	
3696.87	OH	Stretching free
3646.73	OH	Stretching bounded
3619.73	Starch [sizing material] ا	
3380.6	Hydroxyl group	

2915.84	C-H	Stretching for Aliphatic group
1716.34	aromatic aldehydes and aliphatic aldehydes	
1633.41	C=C	Stretching
1511.92	C=C	
1427.07	CH	Bending O-CH_3
1373.07	CH	Bending "symmetric "for CH3
1317.14	OCH_3	Methoxyl group
1268.93	C-O	Stretching
1160.94	R-C-OH	Stretching
1031.73	R-CH_2-OH	Alcohols
1008	R-CH-OH	Alcohols
912.165	Rosin	
667.25	C-CL	Stretching aliphatic aromatic
468.617	C-CL	Stretching aromatic group

Table No. (6) Shows The analysis result of the embroidery metal thread bottom with cardboard filling and identification of its the function groups [28]

3.3. The analysis and investigation results of the samples using the scanning electron microscope with EDAX:

The samples were examined in the Supreme Council of Antiquities Research and Conservation Center using the company frequent 200 SEM with EDAX Unit 2004 model, which is a complex system of different parts of original and non-destructive method of analysis where the sample can be used again. It is also an easy device -to-use that investigates and analyzes at the same time with immediate results [20] as follows:

3.3.1. The investigation and analysis results of the first experiment:

The metal thread was investigated with a 160x magnification which showed the industry technique of metal strip that wrapped around an internal fibrous core in the (S) twist direction as in Figure (18) and the metal threads general condition that were covered with corrosion layers mixed with suspensions and dust

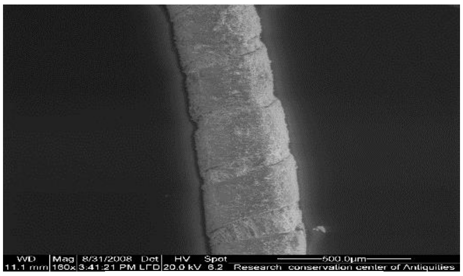


Fig (18)

3.3.1.1. The investigation and images of the result before and after the first experiment:

The metal thread sample was investigated before the experiment with 10,000 x magnification as shown in Figure (19) which showed the heterogeneity of corrosion layers formed on the sample surface. The sample was also investigated after the experiment with 5000 x magnification as shown in Figure (20) which showed The noticeable improvement in the surface condition with the appearance of the metal strip marks and some clarity fractures caused by partial fusion was occurred by using the spherical lens to concentrate the falling rays during the experiment

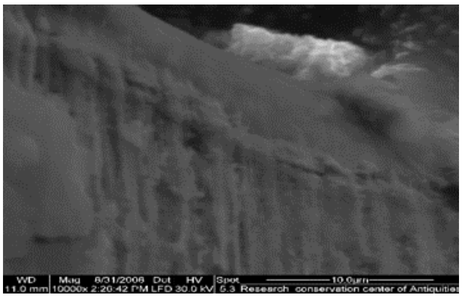


Fig (19)

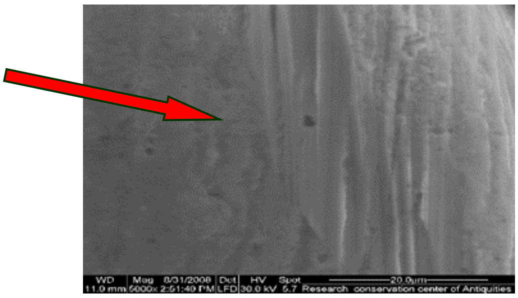
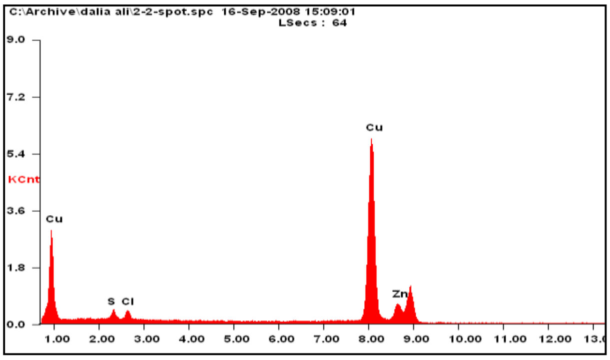


Fig (20)

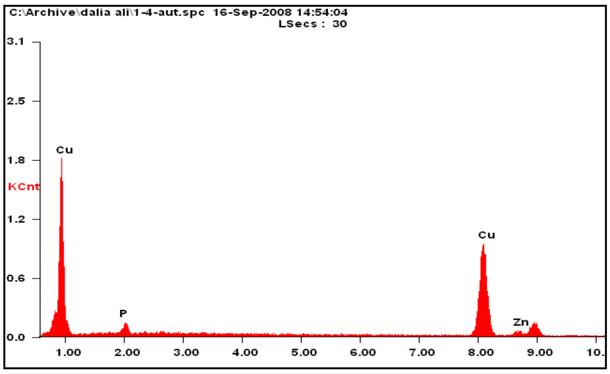
3.3.1.2. The analysis result before and after the first experiment:

The metal threads were analyzed before the experiment. The result is as shown in the table in figure (21), which shows the use of copper alloy of brass for the manufacture of metal threads, which consists of a mixture of copper and zinc with the presence of other elements that may represent dust and dirt. The metal threads were analyzed also after the experiment. The result was shown in the table in Figure (22) which showed the best improvement in the copper ratio that means the increase of copper weight down to 90% of the sample with a decrease in zinc ratio, possibly due to the selective dissolution [32] of the zinc element at the expense of high Copper percentage in the alloy with the disappearance of elements of dust and dirt completely.



Element	Wt %	At %
S K	01.53	02.96
ClK	01.39	02.43
CuK	85.20	83.31
ZnK	11.89	11.30

Fig (21)



Element	Wt %	At %
P K	04.12	08.12
CuK	89.69	86.11
ZnK	06.19	05.78

Fig (22)

3.3.2. The investigation and analysis results of the second experiment:

3.3.2.1. The investigation and images of the result before and after the second experiment:

The metal thread sample was investigated before the experiment with 2000x magnification as shown in Figure (23) which showed the thick crust corrosion layers in some parts. The sample was also investigated after the experiment with 2000x magnification as shown in Figure (24) which showed the absence of the metal thread surface pits because of the reduction of the beam energy. About the beam energy that was used in the first experiment in addition to the use of the cylindrical lens instead of the spherical lens to give a linear laser which succeeded in the removal

of the thick and large crust corrosion layers with the appearance of some prominent protrusions, which called frozen explorations that were caused by the release and extrusion of ionized corrosion components with rapid expansion of plasma due to the impact of the falling beam pulses.

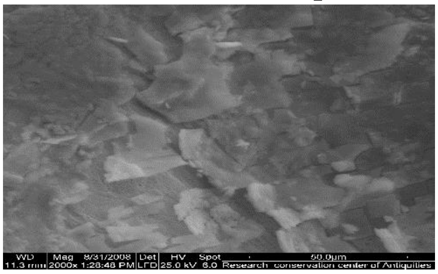


Fig (23)

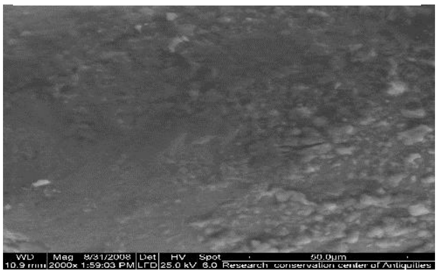
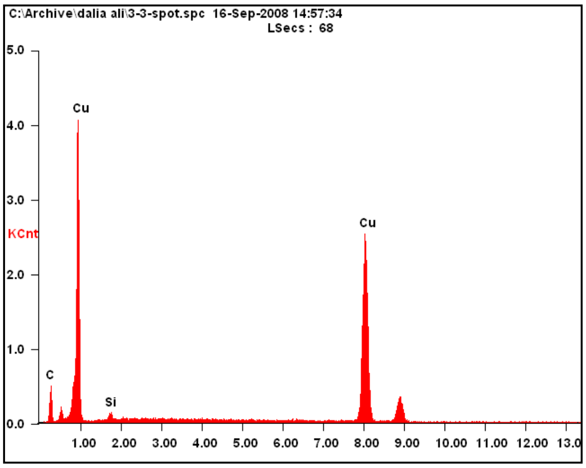


Fig (24)

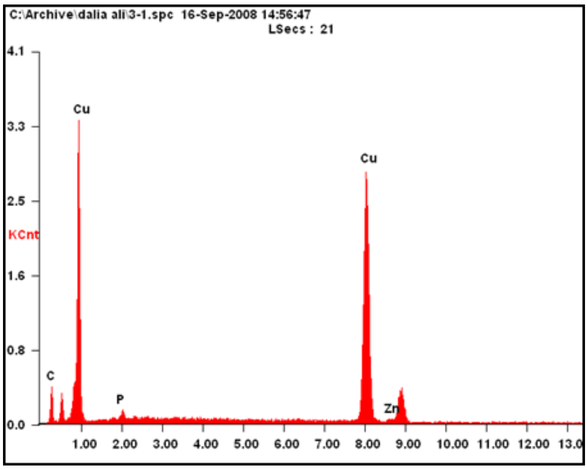
3.3.2.2. The analysis result before and after the second experiment:

The metal threads were analyzed before the experiment. The result is as shown in the table in figure (25), which shows that the thick crust corrosion layers are from copper carbonate malachite mixed with sand, where the carbon ratio increased to more than 40% from the sample weight with the presence of silicon element. The metal threads were analyzed also after the experiment and the result was shown in the table in Figure (26) which confirmed the high percentage of copper and low percentage of carbon, which confirms the effectiveness of using laser as a tool for cleaning, and also considering it as a method for improving the surface and enhance the characteristics of the metal threads.



Element	*Wt %*	*At %*
C K	40.98	78.21
SiK	01.09	00.89
CuK	57.94	20.90

Fig (25)



Element	Wt %	At %
C K	35.73	74.31
P K	01.07	00.87
CuK	62.05	24.39
ZnK	01.14	00.44

Fig (26)

3.3.3. The investigation and analysis results of the third experiment:

3.3.3.1. The investigation and images of the result before and after the third experiment:

The metal thread sample was investigated before the experiment with 1200 x magnification as shown in Figure (27) which showed**:**

The appearance of a rough surface with some corrosion flakes mixed with sand grains and dust. The sample was also investigated after the experiment with 1200 x magnification as shown in Figure (28) which showed remarkable progress in the surface condition and removal of the corrosion components, almost with no pits and protrusions on the surface of the sample.

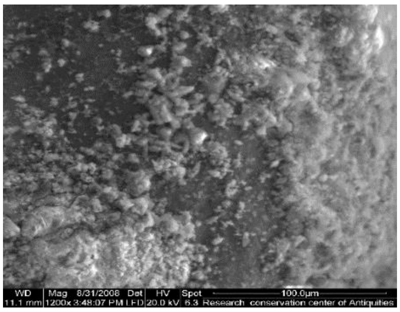


Fig (27)

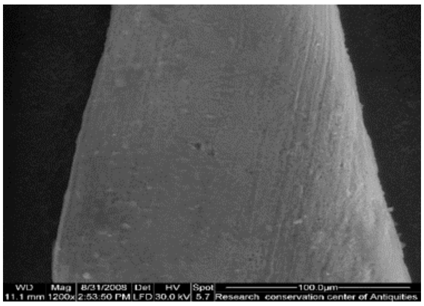


Fig (28)

3.3.3.2. The analysis result before and after the third experiment:

The metal threads were analyzed before the experiment. The result is as shown in the table in figure (29), which showed that the metal threads corrosion crusts represented a mixture of different copper compounds (Cuprite, Tenorite, Brochantite, Nantokite, Chalcocite) mixed with sand. The metal threads were analyzed also after the experiment and the result was shown in the table in Figure (30) which confirmed Kearns and others (14) about the positive effect of the fusion process caused by the laser beam thermal effect during the cleaning process and the occurrence of the metal alloy particles crystallization. This is confirmed by the high proportion of copper metal to 89.69WT% with the removal of all impurities elements, sediments and corrosion layers almost with the surface homogeneity in the shocks position caused by pulses of the laser beam that was confirmed by the crack sound during the experiment.

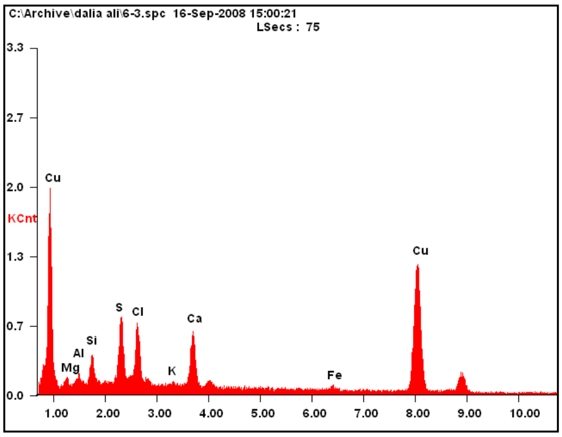
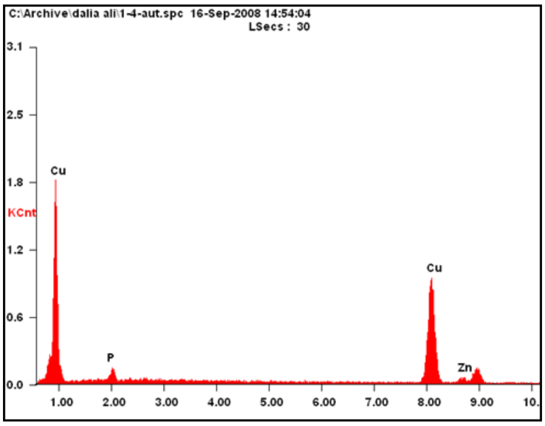


Fig (29)

Element	Wt %	At %
MgK	02.02	04.21
AlK	01.60	03.00
SiK	03.50	06.32
S K	06.54	10.34
ClK	06.12	08.74
K K	00.54	00.70
CaK	06.48	08.19
FeK	01.24	01.13
CuK	71.96	57.38



Element	Wt %	At %
P K	04.12	08.12
CuK	89.69	86.11
ZnK	06.19	05.78

Fig (30)

3.3.4. The investigation and analysis results of the fourth experiment:

3.3.4.1. The investigation and images of the result before and after the fourth experiment:

The metal thread sample was investigated before the experiment with 4000 x magnification as shown in Figure (31) which showed the appearance of thick layers decomposed to corrosion compounds in the pale crusts form of malachite according to the experiment analysis results in addition to the dark crusts of other copper compounds, The sample was also investigated after the experiment with 4000x magnification as shown in Figure (32) which showed the complete removal of most of the corrosion crusts with the metal threads Heterogeneity surface and the spread of cracks in the surface.

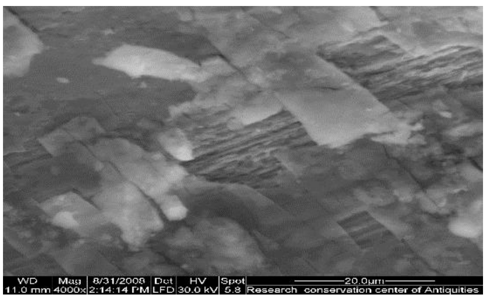


Fig (31)

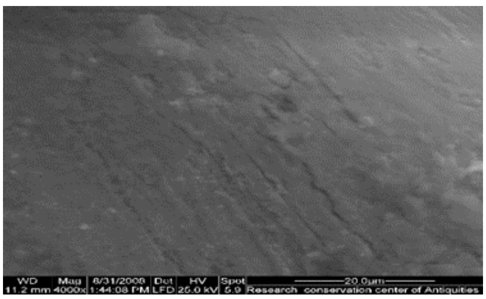
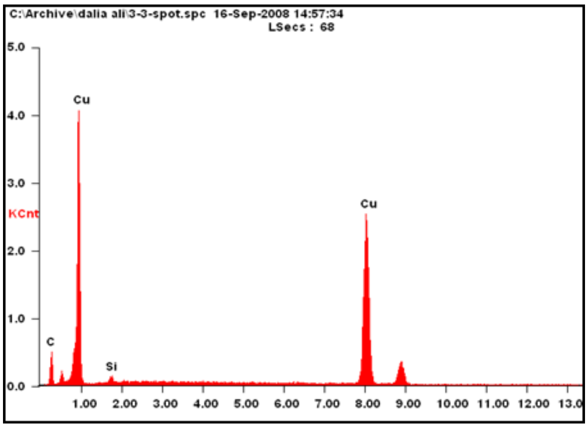


Fig (32)

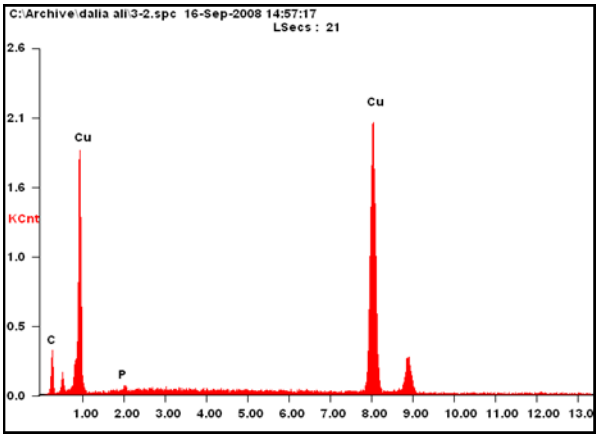
3.3.4.2. The analysis result before and after the fourth experiment:

The metal threads were analyzed before the experiment. The result is as shown in the table in figure (33), which showed that the pale corrosion crusts are composed of malachite mixed with sand and that the dark-colored corrosion crusts are from cuprite and Tenorite, which are common corrosion products. The metal threads were analyzed also after the experiment and the result was shown in the table in Figure (34) which showed a decrease in the carbon percentage of the sample by 3WT%, with increase in the copper percentage by approximately the same percentage due to the selective transformed fusion with the disappearance of the silica percentage of silica which was represented as sand grains.



Element	Wt %	At %
C K	40.98	78.21
SiK	01.09	00.89
CuK	57.94	20.90

Fig (33)



Element	Wt %	At %
C K	35.73	74.31
P K	01.07	00.87
CuK	62.05	24.39
ZnK	01.14	00.44

Fig (34)

3.4. The investigation and images of the result of embroidery metal threads after laser cleaning experiments by using Light Scanner:

Light Scanner is the advanced Imaging Technology and a very modern method , the examination was done in the scientific lab of the conservation center in The Grand Egyptian Museum with100 x magnification as in figure (35), through the analysis of images using optical interference and variable wavelength range to convert the image into a digital accurate system by using the computer with digital camera [7], which showed a good improvement in the removal of corrosion layers by laser cleaning while maintaining the cuprite noble patina layer of the metal without affecting the basic textile strength and also cleaning the textile saturated dirt with testing the laser pulse forces on it.

Fig (35)

4. Conclusions:

The conclusions were presented by presenting the advantages and disadvantages of the laser cleaning applying technique ND: YAG for copper metal threads through the four experimental study as follows:

4.1. Advantages of using laser cleaning technology applications

4.1.1. The 1064nm wavelength laser beam and its thermal mechanical effect gave great benefit and encouraged positive results in cleaning and removing dust, sand grains and improved the surface condition that was examined and analyzed by the study.

4.1.2. The use of laser technology is a very effective method that has demonstrated its ability to preferentially selective dissolution of the copper element at the expense of the zinc element in the yellow brass alloy of the embroidery metal strip threads. It is fully controlled by determining the place to be cleaned and directing the impulses to it except for other damaged and corroded places (5).

4.1.3. The positive compatibility between the laser beam and the special nature of the metal embroidery threads, where the laser beam has been able to clean the narrow intervening places in the embroidery damaged and corroded areas without any deformation of morphological details, which were confirmed clearly by the appearance of forming and cutting marks of the metal strips after the cleaning process (21).

4.1.4. We can say that laser cleaning technology is one of the most appropriate, safe and clean application methods, either on the objects with all its inorganic and organic components (19) or on the conservator due to the absence of any vapors, penetrating odors or harmful compounds like the other traditional mechanical and chemical methods (9).

4.1.5. The laser has achieved high levels of quality and effectiveness to solve the problem of cleaning metal embroidery threads in addition to being a relatively moderate cost technique. (13) Therefore, the specialized restoration laboratories in all our museums must work on using this technology within their cleaning methods with the assistance of specialized physicists to help the conservators of the textile embroidered with metal threads.

4.2. Disadvantages of using laser cleaning technology applications:

4.2.1. The use of the spherical lens to focus the laser beam of large operating power to the emergence of some small surface drilling, with the erosion of the noble patina layer and the appearance of clear luster.

4.2.2. The concentration of high-energy pulses directed at certain locations on the metal thread surface results in discolored black spots after laser treatment and cleaning.

4.2.3. Laser cleaning takes a relatively long time, as it requires special equipment for adjusting the system according to each piece, since each textile item is a special condition.

4.2.4. The laser cleaning technology is a very specialized technology that cannot be performed by any beginner conservators without fully preparing for them to achieve the best results with continuing the scientific research and serious studies to add more conclusive results to this field.

Thanks and appreciation:

I would like to express my thanks and appreciation to both of Prof. Dr. Hisham Imam, Professor at the National Institute of Laser Sciences for his assistance to conduct the study using laser science applications in the metal embroidery threads cleaning field as a new field, and Prof. Dr. Monza Khafagy Professor of Spectra, Department of Geophysical, researcher at the National Research Center, for her assistance in completing some scientific tests and analysis to achieve the best results.

References:

1) Abd El –Kareem,O., and Harrith M.A., "Evaluating the use of laser radiation in cleaning of copper embroidery threads on archaeological Egyptian textiles" Applied surface science, Journal Home page www.elsevier-2008 – pp 2 : 10

2) Asher C., Shipyard,H., and Company,D., "Factors to consider, chemical and physical aspects of surface cleaning materials" AIC preprints-1981- pp 20 : 25

3) Chung C., lee M., and Choe E.K., "Characterization of cotton fabric scouring by FT-IR" ATR spectroscopy- carbohydrate polymers 58-2004-pp 417: 420

4) Copper M., "Laser cleaning, in conservation" Butter worth- Heine mann- London-1998 – pp 1 : 13

5) Degrigny C., Tanguy,E., and Renelagall "Laser cleaning of tarnished sliver and copper threads on Museum textiles" – Journal of cultural Heritage -2018- pp 1 : 5 www.elsevier.com/locate/cultural

6) Ding Y., " Monitoring Excimer laser cleaning process of titanium alloys-A thesis submitted to the university of Manchester for the degree of Master of philosophy in the faculty of engineering and physical science – 2011 . pp 21 : 23

7) Ektessabi A.I., "Advanced Imaging technology- Ide project" the Kyoto system for E-Heritage, graduate school of engineering, Kyoto University Japan-2011-pp 1 : 38

8) Fotakis C., "Laser technology for the preservation of cultural heritage, diagnostic and Restoration Applications" Univ. of Crete-Greece – 2003-pp 1 : 2

9) Fotakis C., Zafiropulos, V., and Anglos D., ETAL"Laser in art conservation" In interface between science and conservation, preprints of the conference organized by the British Museum, April 1997-pp 83 : 90

10) Fulya,B., " The art of Turkish metal working " Istanbul – 1987- pp 90 : 105

11) Jaro M., and Toth, A., " Scientific Identification of European Metal thread manufacturing techniques of the 17 : 19th centuries " New York 1991-pp 175 : 184
12) Jaro M., " Effect of different treatments on textiles with metal threads " – National Center of Museums –Budapest , Hungary 1990- pp 83 : 86
13) Kautek W., Pentzien, S., Rudoplh, P., Konig, E.,. "Laser interaction with coated collagen cellulose fiber composites" fundamentals of laser cleaning of Ancient parchment manuscripts and paper, applied surface science, federal Institute for materials Research and Testing-Berlin-Germany- 1998- pp 746 : 754
14) Kearns A., Fischer C., and Watkins K.G., "Laser removal of oxides from a copper substrate using Q-switched ND: YAG radiation at 1064nm, 532nm and 266nm" applied surfaces science, Department of mechanical engineering-university of Liverpool, U.K. 1998 – pp 773 : 780
15) Koh Y S., "Laser Cleaning as a Conservation Technique for Corroded Metal Artifacts" Doctoral Thesis -Division of Manufacturing Systems Engineering Department of Applied Physics and Mechanical Engineering - Luleå University of Technology- Luleå, Sweden December 2005- pp 31:45
16) Koh Y., and Sarady , I., "Cleaning of corroded Iron artifacts using pulsed TEA CO_2 and ND: YAG – lasers" Journal of culture Heritage 4 , 2003 – pp 129 : 133
17) Kozocsa I.B., "The Conservation of Two Medieval Parchment Codices ICCROM Conservation Studies 7 – 2004- pp 30 : 40
18) Landi S.," The Textile Conservators Manual " 2 ed Edition Heiremann- Butterworth London 1992 – pp 95 : 98
19) Lee J.M., "Process and intelligent monitoring systems for laser cleaning process" Cultural Heritage, 4., 2003-pp 157 : 161
20) Liou Y ., Chau K., Hui C., He J., Lam Y., and Kan C., " An analysis of effect of Co2 laser treatment on carbon fiber fabric" Coatings journal- 2018-8-178 MDPI- Basel- Switzer Land –b-2018- pp 3 : 11
21) Magyen T.M., and lauis "Acleaning of danguerros types with an excimer laser, studies in conservation, Vol., 43.,1998-pp 85 : 95
22) Oh S.,Yoo D., Shin Y., and Seo G.," FT-IR analysis of cellulose treated with sodium hydroxide and carbon dioxide" Carbohydrate Research 340- 2005- www.elsevier.com / locate / carbpol.
23) Pouli,P., Anglos,D., and Fotakis,C.," Laser in the study and conservation of cultural Heritage objects in the eastern Mediterranean" IIC contribution to Istanbul congress-2010- pp 260 : 270
24) Raditoiu V., Chican I.E., Raditoiu A., Fierascu I., Fierascu R., and Fotea P., " Application of Fourier-transform infrared Spectroscopy (FTIR) for the study of cultural heritage artifacts-11internation conference on VR technologies in cultural heritage - VRTCH-2018 – pp 3 : 9
25) Reponen T.H., "The effect of conservation wet cleaning standard solid wool fabric, some Experimental work" ICOM Washington D.C. 1993- pp 320 : 322
26) Ristić S., Polić S., Radojković B., Zrilić M., Heinemann R.J., "Laser Cleaning of Textile Artifacts with Metal Threads: Process Parameter Optimization " Scientific Technical Review, 2014,Vol.64,No.4,pp.45-52
27) Roeges N.P.G., "A guide to the complete interpretation of infrared spectra of organic structures" Chichester wiley1994-pp 741: 748

28) Scibe C., " Metal threads in Hisbano Islamic textiles (11^{th} – 15^{th} Centuries) scientific investigation of the manufacturing techniques and comparative studies with metal threads in Sicilian-Islamic textiles and Lucchese medieval textiles – IPCE,Spain:OPD,Italy-2017 – pp 3 : 12
29) Tiamr – Balazsy, A., and Eastop,D., " Chemical principles of textile conversation " Butter worth – Heinmann – Great Britain -2002 – pp 243 : 248
30) Tiamr – Balazsy, A.," The restoration of 15^{th} century chasuble" conservation and restoration of church textiles and painted flags- national centre of museums- 1984 – pp 125 : 136
31) Watkins K.G., "A review of materials interaction during laser cleaning in art restoration" proceedings of LACONA 1, Heraklion- crete, Greece- 4: 6 October -1995.
32) Weisser T.S" The dealloying of copper alloys" IIC , Stockholm, 1975- pp.207: 214

Arabic References

33) Abd elwahab , Mohamed fahmy " Drasat nazaria w amalia fe hakl alfenon alasarya w torok w mawad al tarmem al hadetha " matabea dar el shaab – 1974-pp 570 : 571
"theoretical and practical studies in the field of archeological arts, means and materials of modern restoration"
34) Badawy , Magdy Mansour " Elag w syana baad aykonat altambra fe maser tabka lahdath al asaleb al tatbekia al alalmia al hadetha " " resala doktora – Gamaa al Kahera – kolia al asar – kasm tarmem – 2001 –pp 163: 164
"treatment and maintenance of some icons un Egypt according to the most modern, international and applied means" PHD thesis- Cairo university- faculty of archeology- department of restoration.
35) Helmy, Ibrahim" Keswat al kaba al mosharafa w fenon al hogag "al tabaa al ola- Ain lldrasat w al behos al ensaniya w al egtmaiya - 1994 – pp 12: 15
"covers of the Holy Kaaba and arts of pilgrims" 1st edition, Ain for humanitarian and social studies and researches.
36) Khalifa , Rabia Hamed " alfenon al aslamiya fe al aser alothmany " Maktabt zhraa el shark – 2005-p 239
"Islamic arts in Ottoman era"
37) Mayer L "almalabes altorkia " targamet Salah Alshety – alhaia al ama llketab –1972- pp 100 : 105
"Turkish costumes"
38) Morsy Esam Adel " ashghal al naseg fe maser fe ahd osrat Mohamed Aly " resala doktora – Gamaa al Kahera – kolia al asar – kasm al athar al eslamia – 2002 -215 : 220
"textile in Egypt during the period of Mohamed Aly family" PHD thesis- Cairo university- faculty of archeology- department of Islamic archeology.