



ALEXANDRA MARIA IOANEŞ
BSc in Conservation and Restoration

FROM USE TO MUSEUM

A COMPREHENSIVE INVESTIGATION OF MAINTENANCE,
CONSERVATION AND RESTORATION PRACTICES FOR UTILITARIAN
SILVER ALLOY OBJECTS

MASTER IN CONSERVATION AND RESTORATION
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Adviser: Isabel Tissot

Researcher, NOVA University of Science and Technology (NOVA FCT)

Co-adviser: Ninette Sammut

Head of the Inorganics Object Department, Heritage Malta

Examination Committee:

President: Dr. Joana Lia Ferreira,

Assistant Professor at DCR, FCT-NOVA University

Examining Dr. Paula Menino-Homem,

Member: *Assistant Professor, Department of Heritage Sciences and Techniques, FLUP*

Supervisory Dr. Isabel Tissot,

Member: *Assistant Researcher at the Department of Physics, FCT - NOVA University*

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From Use to Museum: A Comprehensive Investigation of Maintenance, Conservation and Restoration Practices for Utilitarian Silver Alloy Objects

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To my beloved godmother, Adina

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“Things are not difficult to make; what is difficult is putting ourselves in the state of mind to
make them.” (Brâncuși).

ABSTRACT

Utilitarian silver alloy objects hold material potential for investigating their use, earlier repairs which occurred throughout their functional use, as well as the evolution of the conservation and restoration practices performed after their cessation of use. This information can be acquired through the study of their marks of use, wear, repairs and restorations which reflect historical practices. Even though they are an important part of the object's history the study of ancient repairs and structural reinforcements remains limited.

This thesis aimed to fill in those gaps by studying ecclesiastical silver alloy objects, from Malta, focusing on the manufacturing techniques, corrosion behavior, mechanical deterioration, and past interventions. Three case studies were examined: an 18th-century silver alloy lamp and two altar cruets with silver filigree decoration. These objects were subjected to visual and stereomicroscopic exams to assess the use patterns, historical repairs and past restorations, 3D scanning to document them, radiography for the identification of cracks and other structural damages, and XRF spectroscopy to determine their elemental composition and any variations between the repairs and original material.

The results reveal that the objects were manufactured using techniques such as *repoussé*, chasing, filigree, and casting, each influencing their structural stability. Corrosion was found to be primarily sulfur-based, with environmental factors such as Malta's high humidity and exposure to sea salt aerosols accelerating deterioration. Mechanical alterations included stress corrosion cracking and corrosion fatigue, exacerbated by cold-working, probably

insufficient annealing during manufacture, as well as the influence of the environmental conditions and material susceptibility. Ancient repairs, including soldering and patching, were identified as functional rather than aesthetic reflecting the importance of preserving the utilitarian objects as functional and the common practices applied to maintain this, while the conservation and restoration actions prioritized the aesthetics.

The study highlighted the importance of recognizing traces of use, and repair as integral to the object's history especially in the case of utilitarian silver objects and proposed conservation approaches that preserve both structural stability and the history of use and repair of those artifacts.

RESUMO

Os objetos utilitários em liga de prata constituem um valioso testemunho material, permitindo investigar não apenas a sua utilização e as reparações realizadas ao longo da sua vida funcional, mas também a evolução das práticas de conservação e restauro aplicadas após o seu de-uso. Esta informação pode ser obtida através da análise das marcas de uso, reparações e intervenções de restauro, que refletem práticas históricas específicas. Apesar da sua relevância para a compreensão da história do objeto, o estudo das reparações antigas e dos reforços estruturais permanece ainda pouco explorado.

A presente tese tem como objetivo colmatar essas lacunas através do estudo de objetos eclesiásticos em liga de prata, provenientes de Malta, com enfoque nas técnicas de fabrico, no comportamento de corrosão, na deterioração mecânica e nas intervenções de restauro anteriormente realizadas. Para tal, foram analisados três estudos de caso: um candeeiro em liga de prata do século XVIII e dois galheteiros de altar, em liga de prata, com decoração em filigrana. Estes objetos foram submetidos a exames visuais e estereomicroscópicos para avaliar padrões de uso e desgaste, reparações históricas e intervenções de restauro. Complementarmente, recorreu-se à digitalização 3D para a sua documentação, à radiografia para a identificação de fissuras e outros danos estruturais e à espectroscopia de fluorescência de raios X (XRF) para determinar a sua composição elementar e eventuais variações entre as reparações e o material original.

Os resultados demonstram que os objetos foram fabricados recorrendo a técnicas como o repoussé, a fundição, a cinzelagem e a filigrana, cada uma exercendo influência distinta na sua estabilidade estrutural. Verificou-se que a corrosão era predominantemente resultado da formação de compostos à base de sulfuretos, acelerada por fatores ambientais, como a elevada humidade relativa de Malta e a exposição a aerossóis de sal marinho. As alterações mecânicas identificadas incluíram fissuras por corrosão sob tensão e fenómenos de fadiga por corrosão, agravados pelo trabalho a frio — provavelmente devido a um recozimento insuficiente durante o fabrico —, bem como pela ação das condições ambientais e pela suscetibilidade intrínseca do material. As reparações antigas, realizadas através de soldagens e remendos, revelaram-se essencialmente funcionais, em detrimento da dimensão estética, refletindo a importância atribuída à preservação da funcionalidade dos objetos utilitários e às práticas correntes adotadas para a sua manutenção. Em contraste, as intervenções de conservação e restauro mais recentes privilegiaram sobretudo a vertente estética.

O estudo evidenciou a relevância de reconhecer os vestígios de uso, desgaste e reparação como parte integrante da história do objeto, em particular no caso dos artefactos utilitários em prata. Esta investigação propõe abordagens de conservação que salvaguardem não apenas a estabilidade estrutural, mas também a memória material do objeto, preservando a sua história de utilização e de intervenções ao longo do tempo.

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GLOSSARY

- Utilitarian object** Object that had a previous utility; were used for a purpose by someone and created with the intent of having a specific functionality. “Object genre including items, equipment, accessories, and other things that are utilitarian in purpose rather than purely decorative. Objects having a primary purpose of being useful and used, rather than purely decorative”^[1].
- Musealisation** Pieces that are integrated in a museum’s collection, which are either placed in the deposit or exhibition. “From a strictly museological point of view, musealisation is the operation of trying to extract, physically or conceptually, something from its natural or cultural environment and giving it a museal status, transforming it into a musealium or ‘museum object’, that is to say, bringing it into the museal field”^[2].
- Ancient Repairs** Repair is the act of repairing something damaged, being it gluing, soldering or reducing plastic deformations for metals. “Make good and

return to working order [...]”^[3]. Ancient repairs is used within this document for repairs that were performed during the active life of an utilitarian object. The time frame between their manufacturing and musealisation.

Maintenance The act of maintaining an object in good conditions, i.e. functional condition. In the case of utilitarian objects keeping them functional by checking them periodically, cleaning them and repairing or replacing broken or missing elements. “Taking action which keeps people, physical objects, or property operational or sustains them in their existing state”^[1].

Ancient restorations Past restorations that were performed on an object with the intent of restoring its functionality, aesthetics or both. They were performed in the past, after musealisation of an object, using the materials and techniques known at that time, and might not be up to date.

Ecclesiastical “Belonging to or connected with the Christian religion”^[4].

Ewer “A pitcher for pouring water. It is typically made of silver or another precious metal, or pottery. An ewer may be used to pour water into the font before the prayer of thanksgiving over the water at baptism”. In the present study, the term ewer is used as a singular form of the cruets ^[5].

ACRONYMS

3D	Three-dimensional
C-F	Corrosion Fatigue
EDS	Energy Dispersive Spectroscopy
PM	Particulate matter
RH (%)	Relative humidity (in percentage)
SCC	Stress Corrosion Cracking
SEM	Scanning Electron Microscopy
UKIC	The United Kingdom Institute for Conservation
XRD	X-ray Diffraction
XRF	X-ray Fluorescence

SYMBOLS

μA	Microampere is a unit of electric current, equal to one millionth of an ampere (symbol: μA).
α	Alpha symbol, the first letter of the Greek alphabet. Used in the present study for the silver-copper alloy phase diagram. α phase represents a solid solution of Ag in Cu (Cu-rich phase).
β	Beta symbol, the second letter of the Greek alphabet. Used in the present study for the silver-copper alloy phase diagram. β phase represents a solid solution of Cu in Ag (Ag-rich phase).
$\mu\text{g}/\text{m}^3$	Unit measurement for concentration, used to express the mass of a substance, in this study of a pollutant per unit volume of air. The amount of micrograms of a substance present in one cubic meter of air.

INTRODUCTION

Utilitarian silver alloy objects differ from decorative silver artifacts, as their cultural significance is linked to their functionality ^{[3], [6]}. Their frequent handling and active use results in physical damage such as cracks, fractures, and surface scratches ^[6], necessitating structural repairs alongside regular surface cleanings. For example many utilitarian silver objects have components joined through soldering or alternative methods such as stapling ^[7]. Those physical traces reveal the object's ongoing functional use and provide insights into historical maintenance practices.

When musealised, silver objects enter a new stage of their life cycle, being subjected to conservation and restoration. Those are part of the object's history and they offer evidence not only of how the object was conserved and restored in the past, but also of the evolution of these practices over time ^{[8], [9]}. Despite their significance, the study of historic repairs as well as conservation and restoration interventions—especially structural reinforcements applied during the object's functional life—is to our knowledge scarce.

Although the atmospheric corrosion of silver alloys ^{[10], [11], [12], [13], [14], [15], [16], [17], [18]}, as well as the most effective cleaning and protection methods ^[19], have been well studied, the investigation into ancient repairs and historic conservation and restoration techniques—particularly those addressing mechanical alterations—remains relatively underexplored.

Regarding atmospheric corrosion, while most existing studies focus on the role of sulfur-containing compounds in the formation of dark corrosion layers on silver surfaces, the effects of chloride-induced corrosion have received comparatively less attention. This phenomenon is particularly relevant in marine and coastal influenced environments, where silver artifacts are frequently exposed to sea-salt aerosols. Under conditions of high relative humidity, chlorides such as sodium chloride (NaCl) become highly reactive and can contribute to the corrosion process ^[20]. Despite this, the silver sulphide is reported as the main corrosion product of silver indoor ^[21].

Moreover, the studies are scarce when it comes to mechanical deterioration, like stress corrosion cracking ^{[22], [23], [24], [25], [26], [27], [28]}. The manufacturing techniques employed, the material's susceptibility to corrosion, and the influence of mechanical stress—introduced through repeated usage, repairs, or environmental fluctuations—can significantly impact the microstructure and mechanical integrity of the material. These factors contribute to cracking, surface deformations, and material loss, particularly in utilitarian objects, which are exposed to such conditions ^{[22], [26], [27], [28]}.

The potential of studying chemical and mechanical deteriorations and the various methods employed over time—being them ancient repairs or past conservation and restoration practices—provides the opportunity to answer several pertinent questions, such as: how do maintenance actions performed during an object's active use differ from restoration practices conducted after its musealisation, especially in terms of aesthetic choices and material selection?; how pollutants with S and Cl compounds influence the preservation of utilitarian silver alloy objects in museum context?; to what extent is it possible to integrate historical repairs into current conservation practices, while ensuring the long term stability of these objects? Answering to those questions will facilitate the development of informed conservation strategies, ensuring the long-term preservation of the objects.

For this, the study has two primary objectives: i) to address the importance of preserving the material evidence (i.e. use marks, maintenance actions, repairs, past

restorations) of utilitarian silver alloy objects, by investigating their manufacturing techniques, silver corrosion, ancient repairs, past conservation and restoration actions; and ii) to develop strategies for integrating these considerations into current conservation practices.

The study was conducted in the framework of my master thesis developed at Heritage Malta, within the Conservation of Inorganic Materials Department with the collaboration of the Diagnostic Science Laboratory (DSL), as part of an Erasmus+ Traineeship.

The thesis is divided in two parts: i) theoretical framework, addressing ethical considerations in the conservation of utilitarian objects, chemical, electrochemical and mechanical alteration processes in silver alloys, and finally the conservation challenges associated with religious artifacts chosen as an example of utilitarian objects, and ii) examination and analysis of utilitarian silver alloy case studies which have ancient repairs, and were previously restored and conserved after their cessation of use.

The second component of the thesis aims to sustain the theoretical part, by examining and analyzing real objects. For this, three case studies were selected: an ecclesiastical silver alloy lamp and two altar glass cruets with silver alloy filigree decoration, all of them being repaired during their active use and conserved/restored after their musealisation ^[29]. Each object is analyzed in terms of its manufacturing techniques and their impact on its structural stability. Corrosion is studied in the context of Malta's high humidity and exposure to sea salt aerosols outdoor and its probability to influence the indoor environmental conditions, while mechanical degradation is evaluated through condition assessments. The study also examines ancient repairs and past restoration and conservation efforts, particularly highlighting if they interfere with the structural stability of the pieces, aiming to integrate this knowledge into the conservation of the three objects, that preserves material evidence and enhances structural and visual integrity.

UTILITARIAN SILVER ALLOY OBJECTS AND THEIR CONSERVATION CHALLENGES

Silver alloy utilitarian objects are at the intersection of functionality and aesthetics. They have both aesthetic value and cultural significance, closely linked to their functionality. Historically, silver has been a preferred material for making utilitarian objects due to its properties such as durability, malleability, corrosion resistance, and its lustrous and attractive appearance ^[30]. These characteristics have made silver and its alloys an ideal material for the creation of a wide range of objects, from domestic tools to ceremonial artifacts ^[6].

In contemporary contexts, many of these objects have been musealised, transforming their primary function from objects of practical use to pieces of visual appreciation ^[6]. This transition changes their original purpose, emphasizing their artistic properties. Although they are presented as artifacts in museums, their utilitarian origins still influence how they are perceived ^[6].

Conservators are in a delicate situation, because they must balance the objective to preserve traces of use and wear with the need to prevent degradation.

2.1 The Role and Importance of Utilitarian Objects in Society

Utilitarian objects are defined as items “used in everyday life for a definite purpose” ^[30]. The Oxford Dictionary describes “utilitarian” as something designed to be useful rather than aesthetically appealing. These definitions emphasize the practicality of utilitarian objects as defining characteristics. However, contemporary conservation practices of silver alloy pieces often prioritize restoring them to a more aesthetically state, overlooking functional significance.

Konsa ^[30] notes that “Every contact between the object and the world affects the object and leaves its trace.”, which is particularly relevant for utilitarian objects as their extensive use over time enhances their historical value.

The materials used to produce utilitarian objects were selected because they carry symbolic meanings and for their durability, being practical and resistant items ^[30]. Particularly in ecclesiastical contexts, silver's symbolic and physical properties elevate its importance. Silver symbolize prestige and sacredness, underscoring the importance of such objects in religious and social contexts ^[30].

The continuous use of utilitarian objects has left marks, such as wear, or repairs, that connect their history to their functional purpose. These signs are evidence of how the objects were used in their original context. Caple argues that “the older the object is and the more numerous the phases of use and reuse, the greater the difficulty in accurately interpreting it.” ^[31]. This statement is particularly relevant for utilitarian objects, which often have extensive evidence of use and repair.

While reconditioning and repairing heritage objects have been practiced since prehistoric times, such efforts differ from modern conservation approaches ^[30]. Early repairs focused on functionality especially for utilitarian objects, whereas contemporary conservation focuses on preservation with respect to an object’s historical context.

Previous repairs and ancient restorations have provided insight into the evolution of conservation practices. They show how objects were maintained in working conditions, the materials used for repairs, and the techniques applied. Although Kansa ^[30] argues that “the physical damage suffered by an object also means that information about the past has been lost” ^[30], for utilitarian objects, signs of use and damage are part of their history. These marks tell a story of functionality, revealing how, why, and by whom objects were made and used.

Caple and Williams ^[31] argue that collections are organized based on motifs such as belief, curiosity, understanding, aesthetics, monetary worth, memories, and age. For example, religious utilitarian objects, such as silver cruets used during the Catholic Mass, demonstrate the motif of belief, these cruets symbolizing the body and blood of Christ ^[29]. Such objects are not only functional but symbolic, reflecting traditions of forgiveness and spiritual connection.

When utilitarian objects are musealised, they are often viewed from a new perspective, emphasizing their visual characteristics over their functional aspects. Museum visitors are attracted to objects with intricate details and aesthetically appealing, through this preference does not diminish the importance of simpler utilitarian objects; but it reflects the expectations and biases of modern viewers, who are often amazed by visually striking and polished artifacts.

Muñoz ^[9] states that “the only truly authentic condition of anything is the state in which it exists”, highlighting the value of an object’s actual state. For utilitarian objects, authenticity is not diminished by signs of use; rather, these marks enhance their significance by telling their functional history.

2.2 Ethical Considerations in the Conservation of Utilitarian Objects

The UKIC defines conservation, highlighting the significance of use, wear, repairs and past restorations, by “the means by which the true nature of an object is preserved. The true

nature of an object includes evidence of its origins, its original construction, the materials of which it was composed and information as to the technology used in its manufacture. Subsequent modifications may be of such significant nature that they should be preserved"^[31] (UKIC 1983: 2).

One of the central debates in conservation is the concept of an object's "true" or "authentic" nature. What exactly is the true nature of an object? Why is it crucial to our understanding of the object? Historically—and continuing into the present—the concept of true nature has been aligned with the aesthetics of objects, neglecting their functionality, particularly in the case of utilitarian artifacts. This perspective is reinforced by the expectations of stakeholders, including museum curators and private collectors, who associate for example silver with its polished, shiny appearance and want to remove signs of wear and other evidence of use.

However, removing marks of past use, repairs, and past restorations erases a significant part of an object's historical story, changing its cultural significance, especially for utilitarian objects ^[6].

Caple ^[3] defines the objective of conservation using a triangular space in which the extremities are represented by Revelation, Investigation and Preservation (RIP). He associates these objectives with different types of cultural heritage. For example, in conservation of decorative arts, Revelation is usually chosen, aiming to restore and enhance aesthetic qualities of the objects, whereas for archaeological objects, Investigation is prioritized with the intent of uncovering and interpreting historical information ^[3]. For utilitarian silver alloy objects, especially ecclesiastical items, the challenge is balancing objectives. In such cases, the conservation aim should not be to over-prioritize Revelation—as often happens with silver objects perceived primarily as decorative—but to ensure that the signs of use and the passage of time are preserved. However, decision making is a hard task, because it has to consider the state of the object, the meaning of it, its functionality, as well as to align with the requirements of the stakeholders and the current context of the object.

For example, removing past repairs from silver objects such as solders that may not be aesthetically appealing, is a decision based on Revelation, but those solders are integral parts of the object.

From my experience working in conservation and restoration laboratories in Romania, Portugal, and Malta, especially on museum pieces and some of them ecclesiastical ones still in use within the church, I have observed a consistent trend in silver conservation projects: the preference of the curators and stakeholders for restoring objects' surface to their appearance at the time of manufacture. This approach suggests that silver is most appreciated when clean and shiny, leading to the removal of marks that indicate past use, repair, and damage. While this aesthetic preference aligns with traditional perceptions, it risks neglecting the historical and cultural stories associated with utilitarian objects.

Modern restoration and conservation approaches should recognize the value of preserving the material and immaterial stories of these artifacts, including the marks of use, wear and repair, which serve as records of their functional and social roles, especially for utilitarian objects.

CHEMICAL, ELECTROCHEMICAL AND MECHANICAL ALTERATION OF UTILITARIAN SILVER ALLOY OBJECTS

Ecclesiastical silver objects, like most utilitarian silver items, are typically made of silver alloy—most commonly sterling silver, which consists of 92.5 wt% silver and 7.5 wt% copper, and are either used daily during liturgical services, or occasionally in public religious events involving both clergy and laymen ^[32]. Silver is the material of choice for many ecclesiastical artifacts due to the fact that it shows the status of the church, its durability, resistance to corrosion, and aesthetic qualities among which the shiny appearance is worth mentioning because it is sometimes compared to the light of faith ^[33]. Despite these advantages, pure silver exhibits poor mechanical properties. Because of this, a small quantity of copper is often incorporated into pure silver, forming Ag-Cu alloys ^[10]. This addition enhances the hardness of silver and its resistance to mechanical wear and deformation. These alloys offer a cost-effective alternative to fine silver ^[16], while decreasing the melting point, which represents an advantage for the manufacturing processes, as well as maintain the original luster while having relatively high thermal and electrical conductivity. In fact silver has the highest reflectance of all the metals ^[34], being widely used as a solar energy reflector due to its

reflective properties ^[35]. However, despite its high reflectivity in the visible and infrared region, silver has a low corrosion resistance and being alloyed decreases its reflectivity ^[36].

To understand the microstructural properties of sterling silver the interpretation of the phase diagram is helpful, taking into account that in this representation, the alloy system is under equilibrium. Pure silver melts at 961.93°C, while pure copper melts at 1084.5°C. The eutectic point, where the alloy has the lowest melting temperature, occurs at 28.1 wt.% Cu. In the solid state, silver and copper form the α -phase (silver in a copper lattice), the β -phase (copper in a silver lattice), and a eutectic mixture of finely divided α and β grains (Fig. 3.1) ^[37].

For sterling silver, the solidification process results in primarily β -phase grains with small α -phase precipitates forming at grain boundaries as the alloy reaches room temperature ^[37]. The final microstructure can be influenced by cooling rates and processing methods.

Annealing can homogenize the microstructure, eliminating cored dendrites and forming equal dimension grains of the Ag-Cu alloy ^[37].

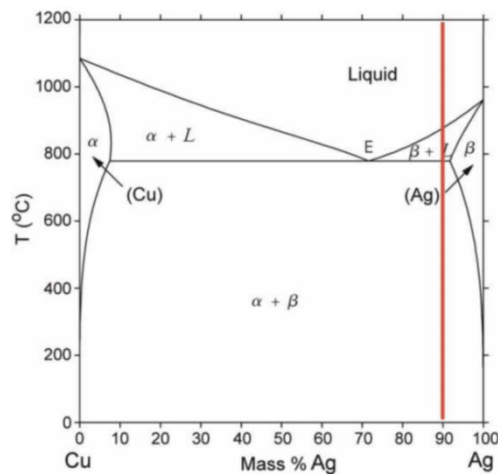


Fig. 3.1 Silver-copper phase diagram. Source: ^[37]

The degradation of silver alloy utilitarian objects is influenced by four major aspects: i) the alloy's constituent elements, ii) the manufacturing techniques, iii) the environmental conditions and iii) the use and wear which can cause mechanical stress.

This chapter examines the mechanisms of atmospheric corrosion of silver alloys, with a focus on environmental conditions similar to those in Malta. Particular attention is given to the silver alloy constituents and degradation, as well as to the role of high relative humidity and airborne sea salts, such as sodium chloride, which are prevalent in coastal regions and can possibly influence indoor environments ^[20]. Additionally, the chapter explores the mechanical deterioration of utilitarian silver alloy objects, emphasizing the impact of manufacturing techniques, repeated handling and functional use over time. Finally, the discussion will address the cumulative effects of use.

3.1 Atmospheric Corrosion Mechanisms of Silver Alloys

Despite extensive research on the atmospheric corrosion of silver ^[11, 13, 15, 38, 39, 40, 41, 42, 43], much of this research has primarily focused on pure silver, rather than silver alloys commonly used in historical objects, while the papers that are dealing with Ag alloys are significantly fewer ^[10, 11, 12, 13, 14, 15, 16, 17, 18]. This limitation is significant because alloys—especially those containing Cu—undergo different corrosion processes compared to pure silver. For example, the potential oxidation of copper is higher than that of silver, as it easily acts with oxygen and sulfur to form oxides and sulfides on surface and thus decrease in corrosion or tarnish resistances ^[14].

The main visual alterations of silver alloys are related to the formation of a blackish corrosion layer that was defined in several ways along the years as tarnishing ^[43]. Many studies describe this tarnish layer as black and dull ^[11, 13, 16, 44]. However, other researchers report that tarnishing can present as a range of color variations, including yellow, orange, red, violet, blue, and eventually grey-black ^[10, 12, 14, 15, 17, 18]. These color variations arise from differences in the composition of corrosion products and the thickness of the tarnish layer.

Silver alloy corrosion is significantly influenced by environmental conditions, particularly relative humidity. Vassiliou and Gouda ^[43] reported that at 90% RH,

approximately eight monolayers of water accumulate on the metal surface, intensifying the degradation process as humidity increases. The strong correlation between humidity and corrosion rate suggests that environments with high humidity, such as Malta—where RH varies from minimum of 61% in July and a maximum of 87% in January ^[45], with meteorological records from 1961-2020 (Fig. 3.2) ^[46]—can accelerate the deterioration of silver alloy objects, leading to more aggressive and rapid corrosion.

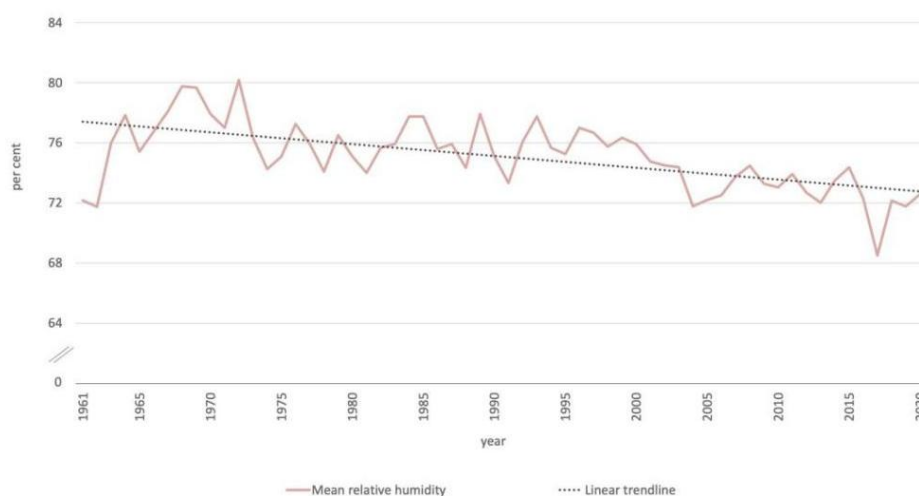


Fig. 3.2 Annual relative humidity in Malta from 1961-2020. Source: ^[46]

In addition to the RH, the atmospheric corrosion of silver is highly influenced by the pollutants present in the air. Silver tarnishing is related to the formation of sulphur-based corrosion products. This tarnishing results from interactions with atmospheric pollutants, particularly sulfur compounds such as hydrogen sulfide (H_2S) and carbonyl sulfide (COS). COS is the most predominant sulfur-bearing gas in the atmosphere, especially in indoor museum environments, and is found at concentrations twice that of H_2S , causing most of the tarnishing ^[43]. Sulfur compounds are also produced by microbial metabolism in the oral cavity and can also be released by human from perspiration, making museum pieces more prone to corrosion due to the number of visitors ^[47]. In this particular case, the H_2S concentrations produced by the museum visitors are between 150-600 ppb per 11 breath air after two minutes of speaking ^[47]. However the concentration of H_2S in a museum vary

depending on the season, number of visitors and the position of the museum. For a museum positioned in an urban area the concentrations are approximately 40-1000 ppb per season ^[47].

In Mediterranean environments like Malta, chlorides are present in the form of airborne particulates that adhere to metal surfaces, promoting the formation of silver chloride (AgCl) ^[20]. Given Malta's insular nature and proximity to the sea, the high concentration of sea salt aerosols must be considered, as these can infiltrate indoor environments through airborne transport. According to ^[48] a pollutant that has been exceeding the EU limit values in Malta is particulate matter (PM₁₀) which can be attributed to salt from sea spray or the Saharan dust. PM can include soluble species such as ammonium salts and chloride aerosols ^[49]. Additionally, many museums and churches housing silver artifacts are located in urban cities such as Valletta, where yacht quays accommodate large cruise ships that contribute to coal combustion emissions. It is known that CO₂, NO_x, SO_x, PM and VOC_s are emitted by ships in ports at arrival or departure or even when they are stationary ^[50], with chlorine being a product of coal combustion ^[51]. For Malta, air pollutants are identified among which it is worth mentioning ozone (O₃), nitrogen oxides (NO and NO₂), sulphur dioxide (SO₂) and PM. The monitoring station chosen for this study was Zejtun station, due to its location closer to the laboratory where the pieces are currently stored and treated. For this station, the mass concentration of PM₁₀ for example is ranging between 16-45 µg/m³, whereas SO₂ is between -0.05 and 0.1µg/m³ and NO₂ 5.1-29 µg/m³ (Fig. 3.3) ^[52].

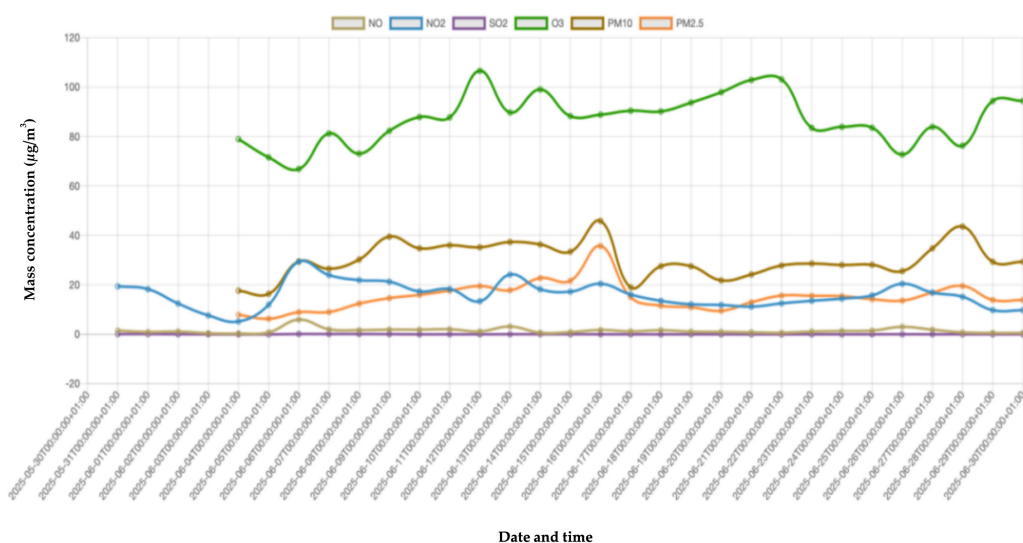


Fig. 3.3 Air quality Graph for Zejtun station including the mass concentration of several pollutants, monitorization 24 hours for one month. Source: [52]

Silver chloride naturally occurs as the mineral chlorargyrite [12] and, while more stable than silver sulfides, it forms highly insoluble corrosion products that are particularly prevalent in areas with elevated pollution levels [11]. In indoor environments, chlorides can be introduced not only via airborne transport but also through human perspiration [47]. This is particularly relevant for utilitarian silver objects that are frequently handled, as chloride residues from perspiration can remain on the metal surface and contribute to localized corrosion. Freshly formed silver chlorides are initially light in color but progressively darken due to photo-oxidation [53]. However, it should be kept in mind that, AgCl is found much more rarely as a surface corrosion product compared to Ag₂S especially in indoor environmental conditions [54]. Outdoor, AgCl was found to be as a main corrosion product by Watanabe et al. [55], its presence in higher concentrations being attributed to sea-salt aerosols from outdoor environment. In indoor settings, Ag₂S, was predominant, demonstrating that silver sulfidation by reduced sulfur gases like H₂S and COS was faster in indoors than outdoors. The predominance of reduce sulfur species compared to chlorine-containing species in indoor environments, favors the formation of Ag₂S over AgCl [55].

Although the influence of Cl ions on the corrosion of silver is recognized, most of the literature is based on the influence of S on the development of the corrosion process, probably due to the fact that Cl is predominant outdoor, while S has been demonstrated to be predominant indoor ^[55]. For example, both Tissot et al. ^{[17], [18]}, and Schalm et al. ^[44] investigated the corrosion of sterling silver and its constituent metals in sulfur environments, revealing that silver and copper corrosion mechanisms are distinct from sterling silver corrosion. Early stages of corrosion in sterling silver showed preferential copper oxidation (Cu_2O , Cu_2S), while prolonged exposure led to silver-based products (Ag_2S , AgCuS). Tissot et al. observed a unique layer-by-layer corrosion structure in sterling silver, absent in pure metals, and linked surface colour variations to the presence of different corrosion products or layer thickness ^{[17], [18]}, whereas Schalm et al. ^[44] also identified void formation beneath the corrosion layer, supporting the conclusion that degradation in sterling silver arises from the interplay of silver and copper corrosion products.

This research is relevant to determine the nature of sterling silver corrosion, however the results are limited, being performed on mock-ups subjected to artificial aging and exposed mainly to sulphide environments. One particular study focuses on real world conditions with contexts similar to the environment of the pieces we will examine, Capelo et al. ^[53], who conducted their research on sterling silver samples exposed indoor in the chapel and museum of Porto Cathedral, in Portugal, revealing that the primary corrosion products were silver chloride, silver and copper oxides, and mixed copper-silver sulfides. Notably, silver sulfide deposits were relatively minor compared to chlorides, a phenomenon attributed to Porto's geographical location near the river and the Atlantic Ocean, which influenced the indoor environment. This study provides a relevant parallel to Malta, which shares more or less similar outdoor environmental conditions, including high relative humidity, sea salt aerosols, and significant atmospheric pollution. However, it has to be considered that the samples from Capelo et al. ^[53] were exposed in the church where the number of visitors is very high being one of the most visited monuments in the north of

Portugal ^[53], and we can assume that the door was opened for long periods of time so the environmental conditions were hard to be controlled in this context, which results in a faster transportation of Cl containing particles indoor, and this is probably the reason the authors found mainly silver chloride. Considering that the pieces which will be examined were also used within the church before being placed in the museum context, the uncontrolled environment within the church is similar to the one in the study, but we also have to keep in mind that the pieces from this thesis were placed in the museum's deposit since the 20th century, where the environmental conditions were controlled.

There are still many questions that need to be answered such as: to what extent do chlorides accelerate corrosion compared to sulfides in indoor environment and do they interact with each other, knowing that silver chloride concentrations are very low indoor?; how accurately do artificial aging experiments replicate real-world corrosion processes in silver alloys?; can the experiments be adjusted to better simulate the multiple sources of pollutants that are in real-world conditions? In the following chapters, the theoretical framework outlined above will be developed through the analysis of the silver alloy case studies that were exhibited in indoor settings, but considering Malta's outdoor environmental conditions and observing if in fact the corrosion of indoor pieces can be influenced by outdoor environment.

3.2 Mechanical Deterioration of Utilitarian Silver Alloy Objects

Stress corrosion cracking (SCC) and corrosion fatigue (C-F) are two significant, yet often overlooked, degradation mechanisms affecting metal alloys. While many articles deal with the atmospheric corrosion, those particular types of corrosion are often disregarded in the cultural heritage field, even though they are a source of failure.

SCC happens when materials crack sub-critically due to sustained tensile loads, either residual or applied, in specific environments ^[27]. Several mechanisms have been proposed for SCC in silver alloys. Pedferri ^[56] highlights two mechanisms:

1. Slip-Dissolution Mechanism – Crack propagation occurs due to anodic dissolution at the crack tip, where the metal dissolves faster than it can repassivate ^[56].

2. Hydrogen Embrittlement Mechanism – Atomic hydrogen generated by cathodic reactions enters the metal and accumulates at the crack tip, reducing cohesion and allowing crack growth ^[56].

SCC often behaves like brittle fractures in ductile materials. Cracks grow perpendicular to the maximum tensile stress direction with an incubation time that depends on metal structure, environmental conditions (salinity, pH, oxygen content) and applied stress. A susceptible metal, an aggressive environment and tensile stress are required for SCC to happen ^[56].

On the other hand, corrosion fatigue (C-F) occurs when metals subjected to cyclic tensile loading experience faster crack initiation and propagation due to the presence of a corrosive environment ^[56]. The degradation mechanism of C-F is linked to the coexistence of mechanical fatigue and corrosion processes. Repeated mechanical loading leads to the formation of microcracks, which are further exacerbated by the corrosive environment ^[57]. The presence of aggressive species, such as chlorides or sulfates, reduces the initiation time by promoting pitting at stress concentration sites, accelerating crack propagation rates ^[57].

Unlike SCC that produces branched crack networks, C-F produces many transgranular cracks that grow perpendicular to the tensile stress direction.

Those types of degradations, namely SCC and C-F occur especially in utilitarian silver alloy objects which are subjected to various environmental conditions, internal stresses caused by the manufacturing techniques, and external stresses through handling, repairing and usage.

One of the manufacturing techniques that affects SCC susceptibility in silver alloys is cold-work, which creates high residual stresses ^{[22], [26]}. Hard drawn or mechanically worked silver objects retain a lot of cold-work and are therefore very susceptible to SCC. These tensions can be decreased during manufacturing with stress relief annealing, but this depends on the artist, and even when final annealed, the pieces can still show signs of SCC. The embrittlement associated with SCC is often intergranular corrosion, which occurs due to copper segregation to grain boundaries. This segregation can occur during fabrication, particularly during cooling after annealing ^{[26], [27]}.

Intergranular SCC in silver alloys is caused by local strains at grain boundaries due to dislocation pile-ups which make these areas anodic relative to the bulk silver matrix. This electrochemical imbalance promotes localized dissolution at the grain boundaries, resulting in intergranular pitting that eventually leads to cracks. Once formed, these cracks develop oxygen-depleted internal environments that inhibit general corrosion, allowing SCC to progress without extensive surface degradation ^[27].

The extent of SCC depends on the amount of retained cold-work. Higher levels of cold-work results to transgranular SCC, which occurs along slip planes rather than grain boundaries. Transgranular cracking is often associated with residual deformation features such as slip lines and twin boundaries, often seen in chased or stamped silver objects that were not annealed after mechanical processing ^{[26], [28]}. Intergranular SCC is seen in mechanically worked and annealed artifacts as well, so it's the most common type of corrosion-induced embrittlement in ancient silver objects.

But why studying those types of degradations are important for utilitarian silver alloy objects? Kerlins ^[57] emphasize that "one of the most important sources of information relating to the cause of failure is the fracture surface itself." This suggests that by analyzing fractures, we can determine their causes and gain deeper insights into the object's history. This is particularly valuable for objects of cultural interest, as studying cracks and fractures can reveal how and why they formed, offering clues about the object's usage and past

interventions. Kerlins ^[57] further argues that “a fracture surface is a detailed record of the failure history of the part. It contains evidence of loading history, environmental effects, and material quality.” By examining fracture surfaces, it is possible to reconstruct the mechanical degradation process and understand the interactions between stress, environment, and material properties.

As referred, utilitarian objects, especially religious artifacts are often manufactured using cold-working techniques such as stamping and chasing to obtain intricate details. Those processes produce high residual and internal stress, and if not annealed the stress can be retained in the metal structure. Stamping and chasing are manufacturing techniques that do not require final annealing, so internal stress produced by those decoration fabrication are indispensable. Cold-working is responsible to both transgranular and intergranular corrosion. When used, those pieces are subjected to frequent external stresses such as hits while handled and material bending while usage. The objects are, as discussed previously, alloys that are prone to intergranular corrosion owing to the precipitation of the solute element copper at grain boundaries which results in fine lamellar structures at grain boundaries ^[22]. This type of intergranular corrosion can result in embrittlement. Furthermore, the pieces are often subjected to various environmental conditions, such as Malta’s outdoor high humidity and salinity due to the insular nature. The cumulus of those environmental conditions, material susceptibility, internal and external stresses results in the production of cracks that can be attributed to SCC.

In utilitarian silver alloys, corrosion fatigue is particularly relevant for objects that undergo repeated mechanical stresses such as material bending that represents a cyclic action (i.e. during use, the object undergoes deformation, followed by a partial reduction of plastic deformations; this cycle of deformation and recovery repeats continuously). Even though corrosion fatigue can cause failure, it is a less discussed topic compared to SCC, so much more attention should be given to this particular type of damage.

Wanhill has conducted extensive studies on SCC analyzing this form of degradation and providing concrete examples of ancient gold, silver, and bronze artifacts exhibiting SCC [22], [23], [24], [25], [26], [27], [28], focusing solely on SCC, while corrosion fatigue (C-F) is overlooked, even though it is a potential contributing factor to crack formation. Furthermore, his study is limited to archaeological artifacts, which are often exposed to highly aggressive environments, such as burial conditions influenced by human decomposition.

In the present work we want to approach the overlooked SCC and C-F on utilitarian silver alloy objects with cold-worked decorations exposed to various environmental conditions mainly indoor, but in the past also influenced by outdoor conditions within the churches, with an emphasis on high humidity and sea aerosols.

3.3 The Impact of Use and Wear on Material Alteration

Utilitarian objects also undergo surface material alterations due to use. These alterations are evidence of how the objects were used and can give us information that is only available through the interpretation of these mechanical alterations. This approach falls into the tribology, the science that studies the mechanical changes which are taking place between relatively moving and interacting solid surfaces. Wear, defined as the progressive material loss from a surface due to mechanical contact, occurs through mechanisms such as adhesion, abrasion, fatigue, and corrosion [58]. In utilitarian silver alloys, these processes manifest as surface abrasions, microstructural deformations, and corrosion-related damage, often exacerbated by repeated handling and environmental exposure.

How an object was used will affect the patterns and extent of wear related degradation. In utilitarian silver alloy objects wear is caused by material displacement due to hard particles embedded in or moving between surfaces. These particles come from environmental contaminants like dirt and dust or from prolonged mechanical interaction with other materials including wear debris [59], as well as handling. Surface asperities and work hardened fragments can abrade and gradually wear away fine details and texture [59].

In religious or domestic silver objects this shows up as scratches, surface roughening and loss of engraved or chased decoration, eventually leading to cracks and ultimately resulting in loss of information.

So why do we analyze signs of use and wear on utilitarian silver alloy objects? The main reason is that wear patterns are a material biography and tell us how the object was handled and used, and the environmental conditions it was subjected to. These marks provide unique evidence of human interaction, as stated previously, that may not be documented elsewhere ^[60]. Also use informs conservation strategy. Since wear is part of the object's history, conservators should be aware of the importance of preserving signs of wear, especially when it comes to silver alloy objects that are usually cleaned using abrasives that can scratch the surface resulting in the loss of wear.

RELIGIOUS SILVER OBJECTS AS CASE STUDY OF UTILITARIAN SILVER ALLOYS

Religious silver objects represent a specific category of utilitarian silver alloys, offering a case study due to their dual nature—functional and symbolical.

Unlike decorative silver artifacts intended primarily for aesthetic appreciation, these objects were actively used in liturgical contexts, often on a daily or weekly basis. Their utilitarian role subjected them to mechanical stress, frequent handling, and environmental exposure, leading to degradations. Their continuous use lead to regular maintenance practices and repairs, and because of those actions, the ecclesiastical pieces were chosen as a representative example of utilitarian objects within the present thesis.

4.1 Use, Wear and Conservation of Religious Silver Objects

The utilitarian role of ecclesiastical pieces which are used daily or weekly subjected them to wear, including surface abrasion, mechanical deformation, and chemical deterioration from contact with substances such as candle soot, incense, wine, oil, and perspiration. These effects are exacerbated by the high humidity and varying micro-climates commonly found in churches, which can accelerate corrosion processes.

Active use often necessitates frequent polishing to maintain a lustrous appearance, particularly during feasts and public ceremonies ^[32], leading to material loss and eventually loss of surface detail. In contrast, storage conditions—often uncontrolled—can expose the artifacts to dust, pollutants, and humidity fluctuations, promoting tarnish and structural degradation.

Historically, the care and repair of these objects were entrusted to local silversmiths, clergy, or custodians, whose interventions prioritized functionality over aesthetics ^[32]. Common repairs included the application of solders, mechanical joins such as wire stitching or riveting with staples, and the replacement of damaged components. While some of these methods reflect a pragmatic approach to preservation, underscoring the continued spiritual and communal value attributed to the objects.

In contemporary conservation practice, such historical interventions should be considered integral to the object's history. Rather than removing these traces, conservation strategies should emphasize documentation, analysis, and—where appropriate—the keeping of past repairs as evidence of use.

4.2 Conservation Challenges of Maltese Religious Silver

Maltese silver religious objects, as part of the Roman Catholic tradition, present a unique set of conservation challenges due to their material, culture and use marks. These objects, from liturgical tools to decorative elements, are part of Maltese religious and social life and are often functional and decorative pieces.

One of the primary conservation challenges is the cycle of intense use, public display, and storage, especially during Malta's annual religious feasts. Objects like chalices, pyxes and service plates are in daily use, while larger processional items, in silver alloy, suffer additional mechanical stress during external processions. These processions, involving clergy and laity, increase the risk of impact, scratches and other physical damage as these heavy items are carried and sometimes knocked against their surroundings. In these events,

parishes present their silverware in ceremonies ^[32], so for this the objects are cleaned using abrasives and commercial products. This frequent polishing leads to surface thinning, loss of detail, and long-term material degradation.

Another major issue is the impact of environmental conditions in Maltese churches. High humidity, driven by Malta's maritime climate, promotes tarnishing and corrosion ^[32], especially in poorly ventilated or unregulated spaces, such as the churches, where the environmental conditions are not controlled. While ecclesiastical silver is often stored in locked cases when not in use, the storage conditions are usually not optimal. Fluctuating temperature and humidity, combined with inadequate padding, improper stacking, or exposure to dust and pollutants, contribute to both chemical and physical deterioration ^[32].

Therefore, ecclesiastical silver is subjected to a variety of challenges such as: the material vulnerability to corrosion and abrasion, the frequent handling and liturgical use causing mechanical wear, the cultural expectations for visual aesthetics encouraging over-cleaning, and the inadequate environmental control during storage and display.

METHODOLOGY

5.1 Case studies selection criteria

To achieve the objectives of this thesis, such as highlighting the importance of preserving the material evidence of utilitarian objects like the use, and to develop strategies for integrating those signs of use and wear in the current conservation practices, we have selected three representative silver alloy case studies: an ecclesiastical lamp, and two altar glass cruets with silver filigree decorations both dating from the 18th century.

In fact the common feature between the three objects is that all of them are made of silver alloy, had a utilitarian function within the church, were previously repaired by laymen or silversmiths, and after their musealisation were conserved and restored in the laboratory.

The pieces were restored and conserved, which means that understanding their history of use and the ancient restorations they were subjected to enabled us as conservators to make informed decisions regarding their treatment, highlighting the importance of preserving the material evidence, while ensuring the pieces stability.

5.2 Examination and analytical techniques

To examine the manufacturing techniques and assess potential degradations associated with these processes, initial macroscopic observations were conducted. Visual inspection facilitated the identification of the fabrication methods employed, the tools used, and any defects or structural weaknesses resulting from the manufacturing process. To obtain a more detailed characterization, stereomicroscopic examinations were carried out using an Olympus SZX16 stereomicroscope at various magnifications.

The assessment of use and wear patterns, historical repairs, and past restoration interventions was performed through both macroscopic and stereomicroscopic exams. These enabled the documentation of surface alterations that can indicate prolonged use, including scratches and plastic deformations, as well as maintenance interventions such as soldered repairs and traces of historical cleaning treatments. To further enhance the documentation of these interventions, 3D scanning was conducted to create high-resolution digital models of the objects. The 3D was captured with an iPhone 16 Pro Max having IOS version 18.4.1 with a triple-lens rear camera system with a 48MP main sensor, a 48MP ultrawide and a 12MP 5x telephoto lens. For this, the Polycam app was used, version 5.0.18, which allows the users to create easy 3D models using photogrammetry, just by moving the camera all around the object.

To investigate structural damage, including stress-induced cracks attributed to use and exposure to varying environmental conditions, as well as historical repair interventions undertaken during the objects' functional lifespan and to assess whether those repairs are still maintaining the structural stability of the pieces, X-ray radiography was performed. Radiographies were acquired using a Rich Seifert-Eresco 42MF-W2 industrial radiography system with an MIR 200 E tube, operated at 80 kV, 5 mA, source to film distance 1.1m, for 18s respectively 36s. The images were acquired on digital imaging plates (IP imaging plate) from Dürr CR and a Dürr HD-CR 35 NDT scanner via the D-Tect version 9.8.0. software.

To determine the elemental composition of the objects, as well as assess potential compositional variations in ancient repairs, specifically the solder used, elemental composition analyses were conducted using X-ray fluorescence (XRF) spectroscopy. Analyses were performed using a Bruker Nano GmbH Artax 800 μ -XRF Spectrometer coupled with a silicon drift detector (SDD). The X-ray tube operated at 35 kV and 250 μ A for 60 s. The spectra were processed by using a Spectra 9 software version 7.6.0.0.

To characterize the current state of conservation of the objects, including the corrosion products, macro, stereomicroscopic examinations and XRF analysis were conducted. To observe all of the signs of use, ancient repairs and ancient conservations, mappings of the objects were done.

The exams and analysis were performed by the Diagnostic Science Laboratory (DSL) at Heritage Malta, and the experimental parameters are in accordance with their reports ^[61].

RESULTS AND DISCUSSION

6.1 Description of the objects

Ecclesiastical silver artifacts in Maltese churches are classified by function. Some objects connected to the altar and tabernacle are used daily, for example the altar cruets, as pair, typically made of glass with silver ornamentation on a single dish, used for the wine and water ^[62]. Due to daily use, these objects undergo repeated handling and polishing, particularly affecting the silver. The altar cruets, which are the case studies of this research, are composed of: the glass body and the silver alloy filigree decorations ([Fig. 6.1](#)), and were likely produced in Malta or Sicily, though their exact origin is unknown without assay marks. The filigree has vegetal and geometric patterns connected by thin silver wires. One cruet's spout has a snake head element with green glass gems for eyes. The cruets' rims and bases were encased in silver. The two cruets were, as mentioned previously used within the church, one for water and one for wine.



Ewer 53856

Ewer 53857

Fig. 6.1 Two glass cruets acc. number 53856 for the left one, and 53857 for the right one, with silver filigree decoration (dimensions: h=21 cm; d=9 cm; weight: 0.28 kg) dated to the XVII century, used in the church, currently stored in the MUŽA Museum ([Appendix A.1](#), [A.2](#)).

Ecclesiastical silver also includes objects associated with lighting, such as lamps which are hung from the ceiling. Those objects, even though are used daily with the purpose of illuminating the churches, are not touched directly nor manipulated. Despite the lack of direct contact, they are susceptible to deterioration. Specific elements such as the chains are under tensile mechanical stress due to the weight of the other elements especially the dome shade or central body of the lamp, ([Fig. 6.2](#)), which is the heaviest part. Because the entire structure is suspended, the gravitational force exerts a continuous downward pull on the mass of the lamp ^[63].



Fig. 6.2 Lamp picture and index

This mechanical stress can lead over time to metal fatigue ^[57], microcracks and in some cases failure of elements, for example broken rings of the chain. Furthermore, the illumination was generally provided by candles for which the lamps had a support inside the dome shade. The heat generated by the flame can also produce deteriorations of the silver alloy material ^{[10], [64]}. It can subject the material to localized thermal stress and repeated exposure to heat can contribute to the oxidation process, softening of the metal, and in particular cases structural deformation ^[64].

From this category we chose as a case study, an ecclesiastical silver alloy lamp (Fig. 6.3). The sanctuary lamp has a thistle shape, decorated with vegetal motifs and specific Maltese symbols.



Fig. 6.3 Ecclesiastical silver alloy lamp (dimensions: h=117.8 cm; l=26.8 cm; weight: 1.48 kg) dated 1715, used in the church Our Lady of Victory in Valletta, Malta, currently stored in the MUŻA Museum ([Appendix A.3](#)).

6.2 Material and Manufacturing techniques: implications for preservation

From the macro observations of the altar glass cruets we were able to determine that the glass was made using the free-blown technique, due to the presence of the pontil mark on the bottom of the vase ^[65].

For the filigree decorations, the general manufacturing process described in literature involves firstly the preparation of the material. For this, the silver alloy is melted and shaped into rods which are then drawn through progressively smaller holes in a draw plate to create the wires ^[66]. The wire is afterwards braided, twisted or looped, in this particular case twisted ^[67]. Then the wires are shaped in the forms desired, for the cruets, floral motifs are used ([Fig. 6.10](#)), and the wires are soldered together. From the discussion with a Maltese silversmith, we were able to understand that the filigree was not casted and in fact it was made wire by wire and soldered together. However, the manufacturing solders have a rough appearance, compared to other filigree works observed in different objects made by the silversmith we have discussed with, which can possibly be attributed to the fact that the filigree of the cruets was made by a beginner or not much attention was given to its solder. To fit the contours of the glass cruets, the design is shaped based on the glass form. This can be either done from the beginning when arranging the wires in the design or after, using cold-working techniques to shape it as a 3D form.



Fig. 6.10 Vegetal decoration silver alloy filigree of the cruets, offering insights on the manufacturing solders and shapes

The stereomicroscopic exams revealed the pattern of the filigree and the places where the decorations were soldered during manufacture (Fig. 6.11, a). It was also identified that the filigree pieces were secured on the glass by small silver wires that connect each piece to form the glass structure (Fig. 6.11, b). This attachment method avoids damage to the glass and allows the decorations to be removable, probably made to facilitate washing the pieces and safely removing the filigree.

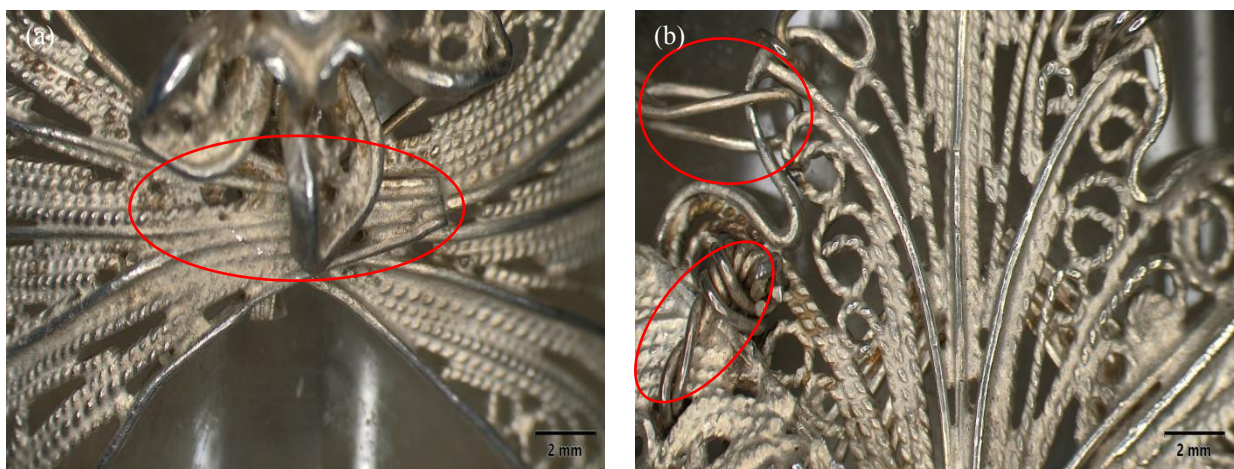


Fig. 6.11 (a) Manufacturing solders having a rough appearance connecting the twisted silver wires that compose the decoration (b) silver alloy wires that connect the filigree parts

From macro observations, it was evident that the ecclesiastical silver alloy lamp was manufactured using the *repoussé* Fig. 6.4, which is both a shaping and decorating technique [68], [69], the term originating from French meaning “driven back” or “to push up or forward” [70], [71], [72]. *Repoussé* involves the hammering from the interior side of the piece while placed face-down on a pitch pad [66], [68], [71]. Most of the tools used for *repoussé* are made out of steel with round or square rods, and are also called chisels [72].



Fig. 6.4 *Repoussé* shaped ecclesiastical lamp with chased vegetal motifs and geometric ones

To enhance the *repoussé*, the silversmith was using chasing decoration techniques. Generally chasing and *repoussé* techniques are used together, with chasing being performed after *repoussé* to refine the forms [72]. The metal was stamped, punched or hammered, but compared to the *repoussé*, chasing is done from the front of the piece [68]. Chasing however doesn't remove metal in contrast with the engraving which does. Various chasing tools are used with different shapes including



Fig. 6.5 Chasing marks, showing several identical tool marks in terms of shape and dimension probably attributed to the use of a specific punch tool

straight liners, running punches, textured tools, matting tools which have different patterns or stamps ^[72]. The use of those tools can be justified by the marks identified through visual observations [\(Fig. 6.5\)](#).

Two of the cartouches from the dome shade had chased decoration [\(Fig. 6.6, a & b\)](#).



Fig. 6.6 Chased (a) Grandmaster Perellos' (1637-1720) coat of arms having two cross decorations and six pears; (b) St. Philip Neri one of the founders of the Congregation of the Oratory in Rome, who has multiple churches dedicated to him in Malta

Engraving was also identified through visual examination on the third cartouche of the dome shade, which has an inscription [\(Fig. 6.7\)](#).



Fig. 6.7 Engraved inscription "Un lampieri fatto per carita; Anno Domini 1715", translated as "A lamp made for charity, in the Year of Our Lord 1715"

The angels (Fig. 6.8) from where the chain is connected were casted having a porous texture especially on the back which is indicative of the sand casting process [73].



Fig. 6.8 Casted angel fixed to the dome-shade with nails

Several components were soldered, especially the rings of the chain and the ones of the angels.

For the chain connectors, it was identified that each of them is marked with assay stamps of the manufacturer using punches (Fig. 6.9). The meaning of the assay marks are as it follows: the letters 'MA' beneath an eight-pointed cross and a closed crown, and the letters 'FA,' which represents the fineness of the silver, a marking style commonly associated with French silver used in Malta (11_{1/2} deniers) [62]. Furthermore, a rosette with five roundels surrounding a central one is also present, which has been attributed to the silversmith Carlo Troisi, Master of the Mint in 1715 in Malta [62].



Fig. 6.9 Assay marks

Elemental analysis obtained by XRF, confirmed that all three objects are composed of a silver-copper alloy (Table 6.1) [61]. In addition, a trace of gold (Au) was identified on the head

of the snake element on one of the cruets ([Table 6.1, Attachment B](#))^[61], which may indicate that this component may have a gilded coating.

Table 6. 1. XRF key elements obtained for the cruets and the lamp with the indication of the analyzed areas^[61]

Object	Analyzed Area	XRF Key Elements
Ewer 53857	Base metal	Ag, Cu
		Ag, Cu, S
Ewer 53856	Snake head base metal	Ag, Cu, S
		Ag, Cu
		Ag, Cu, Au, S
Ecclesiastical lamp	Base metal	Ag, Cu
	Metal detachments	Ag, Cu
Ewer 53857	Solder	Ag, Cu, Zn, S, Ca
		Ag, Cu
Ewer 53856	Chain link solder	Ag, Cu, Zn
		Ag, Cu, S
Ecclesiastical lamp	Patch	Ag, Cu, Zn
		Ag, Cu, Zn, S
		Ag, Cu, Zn, S
		Ag, Cu, Zn
Ewer 53857	Corrosion	Ag, Cu, S
Ewer 53856	Chain link yellow	Ag, Cu, S
Ecclesiastical lamp	Chain link yellow	Ag, Cu, Zn
	Material deposit	Ag, Cu, Al, S, Si

6.3 Chemical, electrochemical and mechanical alterations

6.3.1 Characterization and identification of the corrosion products

The three case studies were showing signs of corrosion, predominantly manifesting as a blackish corrosion layer, uniformly distributed, often defined in literature as tarnish [\[11\]](#), [\[13\]](#), [\[15\]](#), [\[38\]](#), [\[39\]](#), [\[40\]](#), [\[41\]](#), [\[42\]](#), [\[43\]](#).

From the visual examination on the cruets, it was observed that certain areas were exhibiting color variations ranging from yellow, orange, red, violet, blue and dark grey (Fig. 6.12), which from the literature review discussed in Chapter 3 were associated to the different corrosion compounds and layer thickness of silver alloys, especially Ag-Cu alloys [10], [12], [14], [15], [17], [18]. Some areas were having a slightly yellowish surface, also a localized corrosion, which can maybe be associated with the earlier stages of development of the corrosion in Ag-Cu alloys.



Fig. 6.12 Silver alloy corrosion having different color variations aligning with the corrosion pattern of sterling silver

Through stereomicroscopy we also observed the distinctive colors developed during the degradation of the silver alloy (Figure 6.13), which are aligning with the color variations reported by Tissot et al. [17] and Martina et al. [12] for sterling silver corrosion, deducting based on this colours that maybe the corrosion has a layer-by-layer structure.

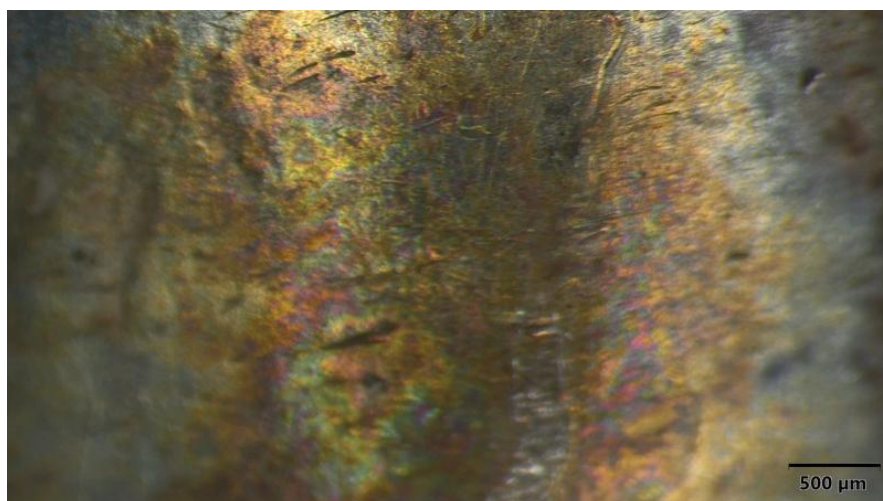


Fig. 6.13 Ag-Cu alloy corrosion with different color variations under magnification

Considering the functionality of the cruets and the wine residues from one of them observed through visual examination, they were in direct contact with wine, respectively water. The red wine usually used within the church to represent the blood of Jesus Christ, may stain the glass. It also has an acidic pH between 3.3-3.6, containing organic acids such as malic, tartaric and citric acids from the natural grape and succinic, acetic and lactic acids from the process of fermentation [74]. Those acids, when in direct contact with silver alloys can contribute to corrosion. Furthermore, the Maltese tap water is known to have a high chloride content, and its direct contact with the silver can further exacerbate corrosion [32].

The XRF analyses detected the presence of sulfur (S) in most of the analysed spots (Table 6.1, Attachment B), suggesting that the main corrosion products are S-based. However, the presence of chlorides can't be excluded, especially due to the environmental conditions with high concentrations of sea salt aerosols that can travel indoor through airborne or due to direct contact of the object with human perspiration. Chloride was not detected in the corrosion products, which is consistent with literature findings that indicate indoor silver corrosion being influenced by sulphur-based compounds [40], [54]. For example acanthite, forms through sorption of the sulfur-containing species (like H₂S or COS) onto the silver surface followed by solid state formation of the corrosion product which strongly adheres to the surface of silver, whereas AgCl is a solution-based precipitation which is less adherent, forming fine-grained corrosion products [54].

6.3.2 Characterization of the mechanical alterations

The macroscopic examination of the ecclesiastical lamp revealed multiple surface scratches and deformations, particularly on the dome-shade component. A fragment of metal was missing along the rim of the dome, and wear patterns were consistent with extensive handling and prolonged functional use. These visual observations formed the basis for the construction of the object's mapping (Fig. 6.14), which documented areas of visible plastic deformation and crack lines, among the other degradations. These cracks were primarily

located below the patches, better observed from the interior, as the patches were applied from the exterior. Those cracks were formed during the active use of the object, and then fixed with silver patches.

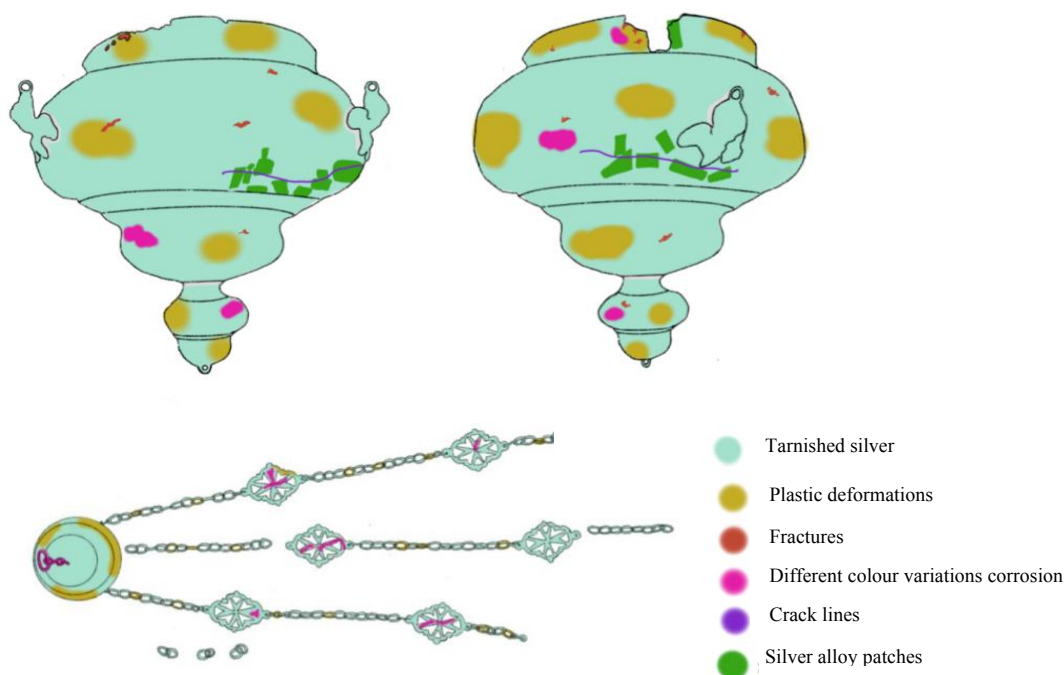


Fig. 6.14 Mapping of the mechanical degradation of the ecclesiastical silver alloy lamp showing several spots with deformations, cracks, fractures, as well as including the tarnished areas

Radiographies ^[61] of the ecclesiastical lamp revealed several cracks not detectable through visual inspection (Fig. 6.15). These were predominantly located in proximity of the patched areas and around zones with more pronounced decorations. Such findings suggest that the thinning of the metal due to *repoussé* during manufacturing may have weakened the structural integrity. Additionally, the cracking could result from SCC or C-F, considering the object's long-term suspension, occasional handling, corrosion and material susceptibility. Another hypothesis is that the object may have experienced a fall, which induced plastic deformation. The attempts to correct this deformation through cold-working may have further contributed to internal stress, resulting in crack formation.

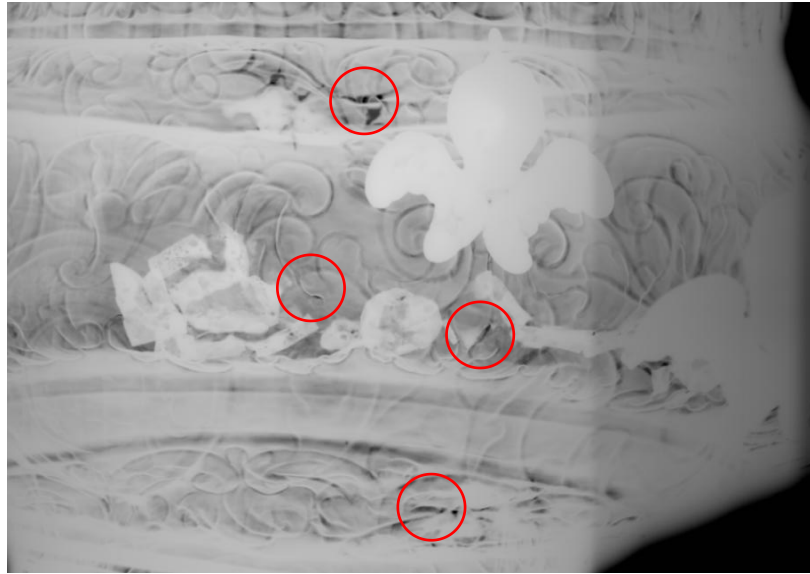


Fig. 6.15 Radiography of the ecclesiastical lamp showing several cracks located next to the patches. Those cracks reveal the inefficiency of the patches and the formation of new cracks throughout time ^[61]

While multiple hypotheses can explain the origin of these cracks, the radiographies helped us in identifying their presence and spatial distribution. For determining the exact cause of the cracks further analyses should be performed such as SEM, metallography or fractography which were used by Wanhill in most of his studies, considering that through those analyses it is possible to observe the fracture surface characteristics, the crack morphology and propagation, as well as to identify the corrosion products by SEM-EDS ^[22], ^[26], ^[27], ^[28]. However, it is worth mentioning that those analyses are invasive requiring sampling, this being one of the reasons why in the present study it was not opted to use such techniques, considering also the museum's decision to not sample the pieces.

The chain of the sanctuary lamp was manufactured with a disproportionately thin wire compared to the weight of the suspended object. This structural imbalance subjects the chain to constant mechanical stress, particularly at soldered joints, where the metal is weaker than the base metal. Over periods of suspension, such stress can lead to deformation and eventually failure of the chain, particularly at these vulnerable joints. A break of the chain results in a risk, as the fall of the object could result in structural damage, including deformation, breakage, and potentially irreversible material loss.

In the case of the altar cruets, visual inspection revealed deformation of the silver filigree decoration. One ewer exhibited a fractured glass body and the complete loss of the silver alloy snake-head element. The other, though structurally intact, had a broken part of the snake-head and surface scratches.

Several micro-cracks were observed through stereomicroscopy in the silver alloy wires of the cruets, that were not visible to naked eye (Fig. 6.16). These cracks are likely attributed to stress during manufacture, particularly from cold-working techniques and improper annealing. Such microstructural stress may lead to SCC. While the contribution of mechanical handling cannot be entirely dismissed, the most plausible explanation involves a combination of factors: material susceptibility, manufacturing conditions, repeated use, and environmental exposure within the church.

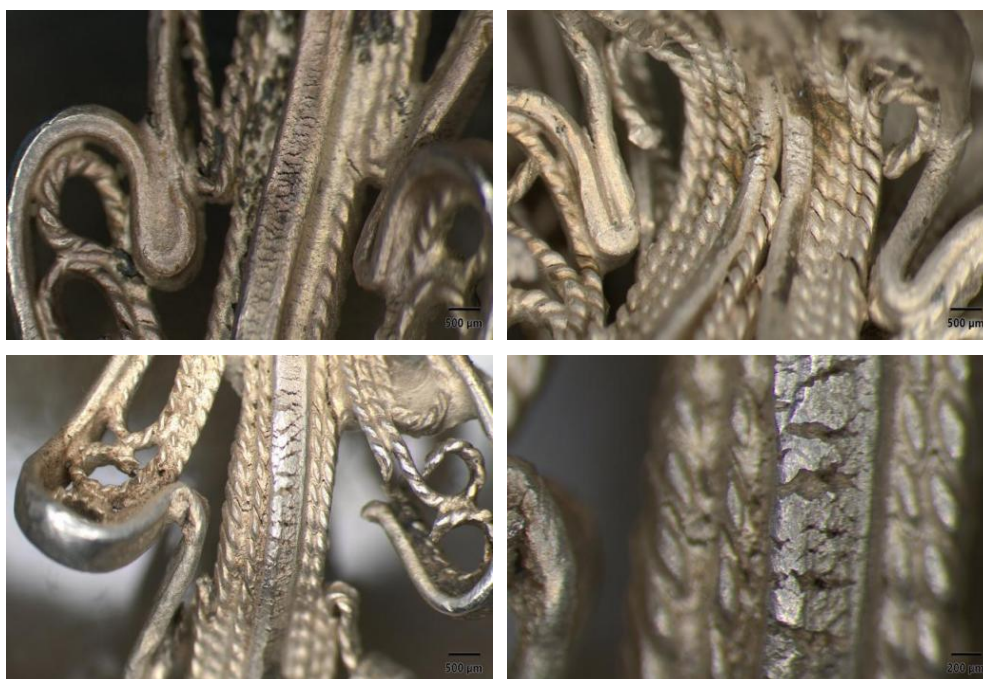


Fig. 6.16 Stereomicroscopic images of silver alloy filigree on the cruets showing micro-cracks which appear as fine, branched fissures along edges and curved areas, likely caused by residual stress from cold-working and insufficient annealing

6.4 Ancient repairs and conservation actions

The three case studies were, as mentioned previously, used within the church until the beginning of the 20th century. During those years, they were repaired and cleaned several times to maintain both their structural integrity and shiny aesthetically pleasing appearance. Those actions were performed by laymen in the church or by silversmiths that were working closely with the church ^[32].

It is worth mentioning that the repairs leave more material evidence than the cleaning actions which are visible only by their residues. The number of cleaning actions can be generally deduced through the wear of decoration features resulting from scratches due to the use of abrasives and etching, when acids are employed. The case studies show evident signs of repairs, particularly patched areas, probably done to prevent crack propagation and to maintain the objects in functional use. To better observe them and be able to do a mapping with the location of all of the patches, as well as determine the different spots with cracks and deformations, 3D scanning of the lamp was done (Fig. 6.17).



Fig. 6.17 3D scanning pictures of the ecclesiastical lamp revealing the areas which have several patches performed during the use of the object that cover cracks

But why do we think that those solders are past repairs? While examining the pieces, especially the cruets, using visual observations and stereomicroscopic exams we were able to see differences between the areas soldered during manufacturing processes which were done very subtle ([Fig. 6.18, a b](#)), blending perfectly with the details of the piece, whereas the solders done as a repair action had a rough aspect ([Fig. 6.18, c d](#)). This can be justified by the fact that the repairs were not performed to enhance the aesthetics of the piece, but rather to stabilize them and keep them functional, and for this purpose the appearance was not considered.

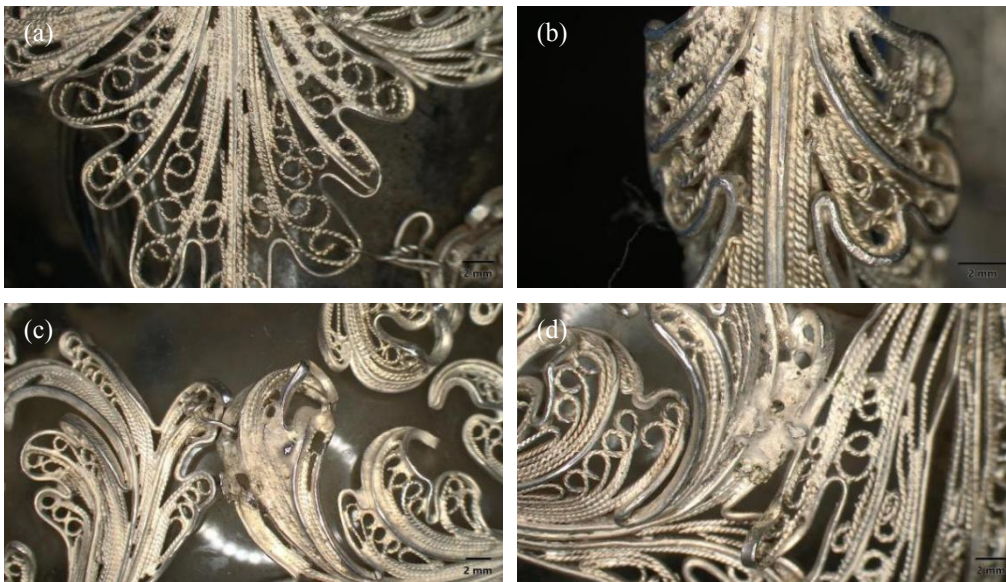


Fig. 6.18 Stereomicroscopic images with the solders: (a) and (b) manufacturing solders having a uniform aspect, connecting the filigree twisted wires; (c) and (d) repair solders with a rough, and bulky appearance, not respecting the pattern of the filigree

To better visualize the solders performed during the repairing process of the cruets, mappings of the degradations and soldered areas were done ([Fig. 6.19](#)).

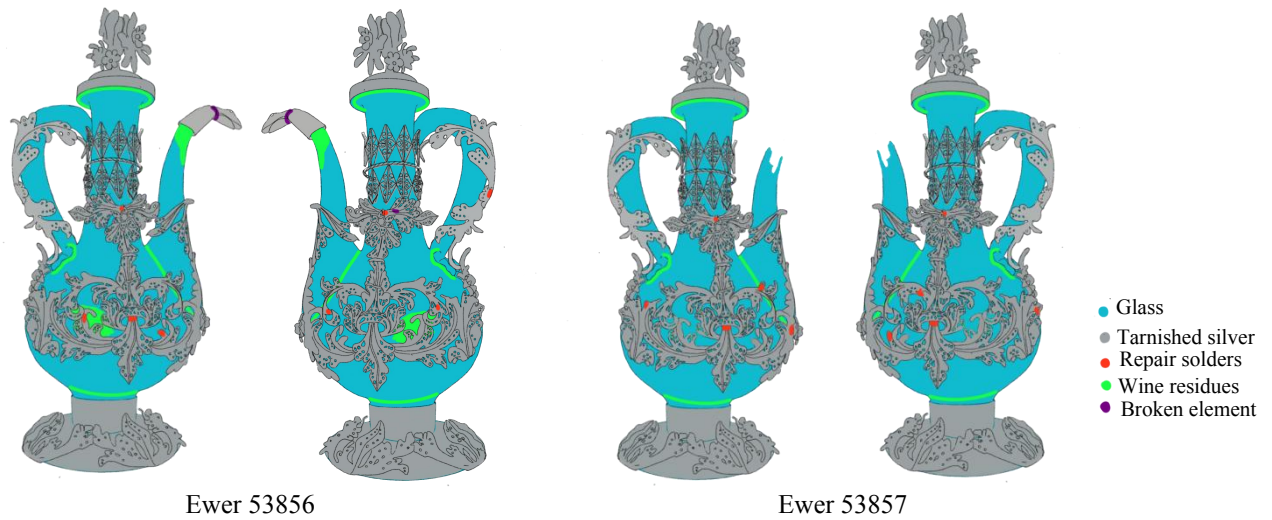


Fig. 6.19 Mapping with the degradation of the two cruets , such as broken elements, missing fragments, tarnished silver alloy, including ancient repairs (solders) in several spots, most of the cruets having solders in similar areas

The solder repairs are mainly located at the center of the middle filigree element and at the midpoint of the neck components (Fig. 23). The consistent placement of these interventions on both cruets suggests that these specific areas were vulnerable and may have required repairs through soldering during the use of the object. The recurrence of soldering in identical locations points out to weaknesses in the original manufacturing process, indicating that these parts may have been prone to mechanical failure from the moment they were manufactured. The presence and distribution of solder repairs reflect the fragility of certain areas from the manufacturing, and provide insight into the original construction methods and the mechanical resistance of the objects.

The ecclesiastical silver lamp has multiple ancient repairs presenting an unusual patchwork appearance, where sheets of silver have been basically glued to the silver using a fluxing agent to cover cracks and structural damages (Fig. 6.20). The majority of the patches are located on the inferior part of the central area of the dome-shaped component, covering a crack visible from the interior.

Some of the patches have decorations (Fig. 6.20), so they may have been produced using cold-working techniques such as *repoussé* and chasing. However, there are differences

between these decorative patches and the original design which might suggest the use of recycled silver by the person who repaired the piece. This interpretation is supported by the lack of coherence between the decorative motifs on the patches and those on the original surface. In contrast, other patches are not decorated and have a quadrilateral form ([Fig. 6.20](#)). From the visual observation of the shape and design of the patches and the fact that they are not homogeneous, we can possibly assume that the patches were placed in different stages.



Fig. 6.20 Repair patches performed on the lamp, having distinct shapes, the red ones being made using repoussé and chased decoration technique, and the ones highlighted with green have no decorations, showcasing the difference between patches

These repairs were not performed with the precision expected from a trained silversmith, suggesting that the work was probably carried out by a non-specialist or someone with limited metalworking experience. This hypothesis is supported by the presence of the patches in photographic documentation found in the Inventory for Special Items ([Appendix A.3](#)), dated at the time of the object's musealisation. The fact that these repairs were already present prior to musealisation indicates that they were made during the object's active use within the church, likely as functional interventions to maintain the lamp's usability—possibly to prevent light from escaping through the cracks.

Further support for this interpretation comes from radiographic exams (Fig. 6.21) ^[61], which revealed bubble-like textures within the solder joints. Such features are characteristic of improper soldering techniques, typically resulting from:

- Inadequate or uneven heating, leading to rapid solidification ^[75], or even lower heating than the melting point of the silver patches which should act as a solder;
- Poor surface preparation, for example failure to adequately clean the base metal, mandatory in most of the soldering processes ^[76];
- Gas voids that form bubble like textures in the solder due to the presence of gas in the process which gets trapped ^{[76], [77], [78]}.

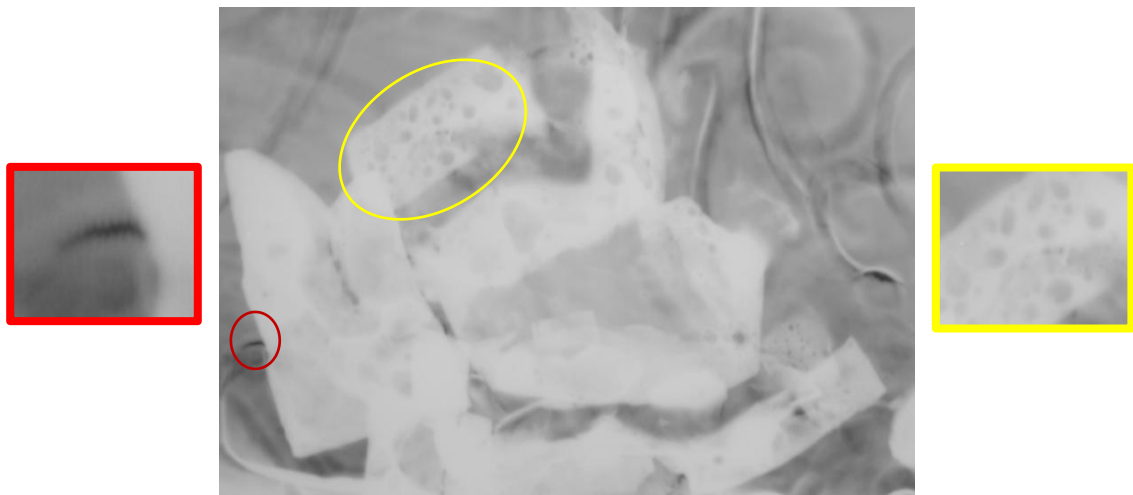


Fig. 6.21 Radiography of the patched areas, the red highlights a crack next to one of the patches, and the yellow shows a detail of the bubble like texture of the silver patches ^[61]

The patches do not function as true soldering repairs, as the original crack remains unsealed beneath them. This is revealed upon examination of the object's interior, where the crack is still visible. Rather than bonding or structurally stabilizing the break, the patches are just hiding the crack beneath them. In the radiography showed above, it was identified that next to one of the patches there is a crack, which if the soldering process was performed correctly should be closed by the solder.

When seeing those repairs, we asked ourselves what would be the differences in the elemental composition of the solders compared to the base material. Usually the solder alloys in the case of silver objects are classified as soft-solders which are containing tin (Sn) and lead (Pb) ^{[79], [80]} or hard solders which are composed of silver, copper and zinc, having a lower melting point than the base material because it contains high Cu contents ^{[81], [82]}. The hard solders are used in jewellery and silverware, which is the case of the ecclesiastical lamp and cruets. The method which is using hard soldering is defined as brazing ^[83]. Soldering and brazing have the same fundamental bonding process—forming metallic bonds at the interface through a reaction, often involving alloying, with the base metal. The main distinction is that brazing uses hard solders with higher melting points, whereas soldering uses soft solders that melt at lower temperatures ^[76].

In this case studies, zinc (Zn) was detected in several of the soldered areas of the lamp ([Table 6.1, Attachment B](#)). The presence of Zn in the solder suggests the use of a silver brazing alloy, which differs in composition from the base material and may reflect the use of brazing as a repair approach.

Following musealisation, the three objects—including the lamp and two cruets—underwent conservation treatments within the Heritage Malta laboratory. This is confirmed by the visual condition of the objects in the same Inventory for Special Items ([Appendix A](#)), which shows them heavily tarnished, compared to when we took the initial pictures and they were cleaner, as well as through discussions with one of the conservators involved in their restoration. According to this source, the objects were cleaned using a variety of commercial products, including Silver Dip, Autosol Metal Polish, silver polishing cloths, and a blue-colored abrasive paste.

These materials indicate the application of mechanical cleaning techniques and commercial products. Visual examination of the lamp revealed residues of white deposits, likely from these past treatments. Given that the most recent intervention occurred in the conservation laboratory, it is probable that these residues are associated with the past

cleaning procedures. The application of silver dips and metal polish pastes remains controversial due to variations in their compositions, which are often not fully disclosed. For instance, the silver dip's safety data sheet reveals components such as thiourea, citric acid, alcohols C12-15 eethoxyled EO (2-5), phosphoric acid, ethanol, and perfume ^[84]. Given the presence of acids, thorough rinsing is essential to prevent surface damage. In the case of the studied objects, the presence of residues observed suggests inadequate removal of the cleaning agents, and this can potentially lead to surface etching caused by the acids.

Cassar ^[32], in his thesis, investigated the cleaning and handling practices of silver ecclesiastical artifacts in 14 Maltese churches. He found that laymen commonly used commercial products like Silver Dip, Silvo (Propan-2-ol, silica amorphous, ammonium hydroxide, Z-octadec-9-enoic acid ^[85]), Autosol (alum earth polishing material, ammonia water, aliphatic, cycloaliphatic and aromatic hydrocarbons ^[86]), and Quick n Brite (sodium cocoate, sodium carbonate, sodium sesquicarbonate, sodium tripolyphosphate ^[87]) to maintain a polished appearance of silver objects, often employing abrasive methods and acids. These frequent cleanings, aimed at aesthetics, risk damaging the objects—abrasives can cause surface scratches and result in the loss of decorative details. Cassar's tests showed that products like Autosol caused significant scratching. His study highlights the long-term impact of these routine practices on the stability and preservation of silver objects.

This distinction raises an important question: How do maintenance practices—such as cleanings and repairs performed during the object's active use—differ from formal conservation interventions in a laboratory setting? The answer lies both in methodology and intent. Church-based maintenance often involved commercial cleaning products applied by non-specialists, potentially causing micro-abrasions and irreversible surface alterations. In contrast the contemporary laboratory-based conservation involves tested materials, applied by professionals guided by ethical frameworks and conservation principles that prioritize both material integrity and historical value.

Another key difference is that repairs that were performed during the object's functional life were clearly aimed at maintaining the pieces in use, often with little regard for aesthetics. Solder patches, for instance, were visually unaesthetic but intended to serve a structural purpose. Modern conservation practices, however, seek to balance functionality, stability, and visual aspect, using materials compatible with the original object and applying them in a way that is



Fig. 6.22 Broken head of the snake element, fixed with Japanese paper and acrylic resin (Paraloid B72)

removable, stable, and visually integrated but not misleading. For example, the head of the snake of one of the cruets was repaired within the laboratory in the past, due to the fact that it was broken, and this was observed through visual examination. Notably, the conservators used Japanese paper soaked in acrylic resin (Paraloid B72 55%) in acetone (Fig. 6.22). The Japanese paper was chosen to offer stability of the broken parts while still allowing for the movement of those elements which represent the mouth of the snake. Furthermore, acrylic resin can be removed [88] later on with acetone.

Metal detachment was noted on parts of the lamp surface (Fig. 6.23).



Fig. 6.23 Metal detachments, observed during the inspection of the piece

Initially attributed to previous cleaning procedures involving acids, mapping of these detachments (Fig. 6.24) revealed that they were predominantly located close to the patched areas. This location suggests that they could have occurred due to thermal stress induced during the heating of the silver in the soldering process and this may have led to microstructural changes or embrittlement, causing the silver layer to delaminate over time.



Fig. 6.24 Mappings with the patched areas and metal detachments of the lamp, highlighting the position of the detachments compared to the patched areas

6.5 Conservation treatment of the case studies

The conservation of the objects was proceeded by a reflective assessment of the manufacturing process, historical context, and the functionality of the pieces. For this, we have decided to retain any signs of use and wear which are part of the object's history, namely the surface scratches, interior of the lamp with the dark residues from the burning, wine residues from the interior of one of the glass cruets, any repairs made during the active use such as solders.

In approaching the conservation treatment of the selected objects, three key factors had to be carefully considered: i) the current state of conservation of the artifacts; ii) the

museum's request to clean the objects to restore their lustrous appearance for exhibition—a common expectation for silver alloy objects; and iii) the need to preserve material evidence of historical use, and previous repairs, where those do not represent a risk to the integrity of the objects.

While choosing the most appropriate conservation methods, we have encountered a challenge, particularly due to the request from the museum collection's conservator to remove the solder repairs and patches performed during the object's liturgical use, due to their unaesthetic appearance. So we had to find an equilibrium between this request and the need to preserve the signs of use and repair through material evidence, in this case the solders and patches. Following the examination and historical research, it was concluded that these interventions do not endanger the object and are, in fact, integral to its history. We explained this to the museum's conservator and the fact that the removal of those interventions would result in a loss of authentic material evidence and compromise the object's historical context.

Traditional cleaning techniques for silver alloys often involve mechanical cleaning, which—although effective at tarnish removal—can lead to the loss of fine surface detail, including tool marks and signs of wear that contribute to the object's historical value.

To address these concerns, a literature review was conducted focusing on innovative conservation materials, together with more traditional methods that are both cost-effective and accessible. Practical constraints, such as the availability of specific tools and materials in Malta, had to be taken into account. For instance, although the electrolytic cleaning pen Pleco has shown promising results in the cleaning of silver alloys [\[89\]](#), [\[90\]](#), [\[91\]](#), it could not be used in this project due to its unavailability at Heritage Malta.

The literature also highlighted widespread use of powdered abrasives like sodium bicarbonate dispersed in water or alcohol [\[19\]](#), [\[92\]](#), [\[93\]](#), [\[94\]](#), [\[95\]](#), [\[96\]](#). While effective, such treatments can compromise surface details—particularly giving rise to problems in the case of these

utilitarian objects selected as case studies, given their intricate decoration and the desire to preserve signs of use which can be abraded due to those treatments.

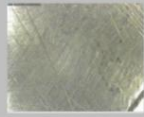
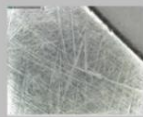

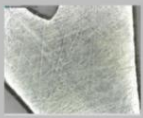
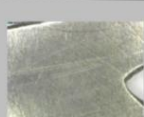


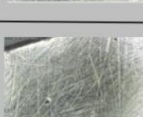
Among the alternatives identified, the eraser with an organic matrix and abrasive (Cretacolor Monolith[®] eraser) emerged as the most viable option [\[96\]](#), [\[97\]](#), [\[98\]](#). Composed of natural gum and fine calcium carbonate particles (1–50 μm), it has been demonstrated to cause minimal surface abrasion while effectively removing tarnish [\[96\]](#), [\[98\]](#). It can be shaped to access relief areas and any residue left behind can be easily removed with a brush and acetone, which does not affect the silver.

In addition to the eraser, other materials commonly used in the Heritage Malta's Conservation of Inorganic Materials Department were also considered, including:

- A rubber sponge made of vulcanized natural rubber, being mentioned in researches for the conservation of metal threads [\[99\]](#), [\[100\]](#);
- A melamine resin foam (Miraclean[®]), generally used with water for dust removal;
- And calcium carbonate in a fine granulation, suspended in water as a paste, which can be particularly effective in treating delicate structures like the wire-based filigree on the glass cruets, and has been used in silver cleaning for several years [\[95\]](#), [\[101\]](#).

Taking into consideration the complexity of the objects in terms of geometry, the literature, and the available products within the laboratory, a series of preliminary cleaning tests were performed, using the four proposed materials: the organic rubber with CaCO_3 particles, vulcanized natural rubber sponge, melamine resin foam, and calcium carbonate paste. They were performed on flat surfaces mainly on the chain connectors of the lamp, because we wanted to observe their efficiency on similar spots. These tests, presented in [Table 6.2](#), were essential to determine the most effective and least invasive cleaning strategy for each object.

Table 6. 2. Cleaning tests using: organic rubber with CaCO₃ particles, vulcanized natural rubber sponge, melamine resin foam, and calcium carbonate paste, advantages and disadvantages

<i>Tarnish removal tests</i>				
	Before	After	Advantages	Disadvantages
Natural Gum and Fine CaCO ₃ Particles Eraser			<ul style="list-style-type: none"> -cost efficient -easy to use -efficient in removing tarnish -no scratches at microscopic level -method tested by several authors -composition known 	<ul style="list-style-type: none"> -residues that are non-adherent, easily removed with a brush -technique can't be used on surfaces with complex decorations such as filigree
Melamine Resin Foam			<ul style="list-style-type: none"> -cost efficient -easy to use -no residues -no scratches at microscopic level -composition known 	<ul style="list-style-type: none"> -not efficient in removing tarnishing -not efficient on complex decorations -not present in any documentation or subjected to scientific tests
Calcium Carbonate+ Distilled Water			<ul style="list-style-type: none"> -cost efficient -easy to use -very efficient in removing tarnishing -composition known -the method has been subjected to various analysis -efficient even on complex decorations as filigree 	<ul style="list-style-type: none"> -white residues left on the surface -can cause scratches at microscopic level if used several times
Vulcanized Natural Rubber Sponge			<ul style="list-style-type: none"> -cost efficient -easy to use -no residues left -it doesn't cause scratches at the microscopic level -composition known 	<ul style="list-style-type: none"> -the dust and dirt can get into the scratches producing a more nuanced black colour due to the friction of the rubber

Among the tested materials, the eraser proved to be the most effective. Its primary advantage lies in its ability to clean without leaving scratches at the microscopic level, thereby preserving the surface features such as signs of use. However, its main limitation is that it can't be applied to intricate details such as silver filigree, as the eraser tends to disintegrate when used on fine, three-dimensional elements.

In contrast, both the vulcanized natural rubber and melamine resin foam were ineffective in removing tarnish. As a result, calcium carbonate paste was tested as an alternative. While it successfully removed tarnish, it posed two notable issues: surface residues that required careful rinsing with distilled water, and a potential risk of surface abrasion if applied repeatedly in the same area or if the abrasive granulation is too large.

After the literature review and cleaning tests, it was decided that the most appropriate cleaning materials that we could use for the lamp and cruets are the: eraser, and CaCO₃ suspended in water. Despite the observed disadvantages of CaCO₃, it is worth mentioning that it is the most traditional cleaning agent widely used in cleaning silver objects, and tested

by several authors. Its long use and well-documented behavior in conservation contexts made it the most ethically appropriate choice for this treatment, especially in the case of the cruets.

For the ecclesiastic lamp, the restoration proceeded by dusting the piece to remove the non-adherent deposits from its surface, using a soft brush. The eraser proved to be efficient in removing the tarnish, and easily to be controlled ([Fig. 6.25](#)). For the chain, calcium carbonate suspended in water in a fine granulation was employed. The residues were cleaned using distilled water locally on a cotton swab ([Attachment C](#)).



Fig. 6.25 Image with the lamp cleaned using the eraser, showing the efficiency in tarnish removal in the brighter area

For the restoration of the two cruets, the CaCO_3 was used, also in a fine granulation suspended in distilled water. We have decided to not detach the filigree from the glass because its removal would result in the loss of the silver wires that are connecting the pieces, which are original. To avoid accidentally scratching the glass, melinex was placed in between the glass and filigree ([Fig. 6.26](#)). In this way, the CaCO_3 was not in direct contact with the glass so it could not create friction. For cleaning all the filigree, a Dremel[®] rotary tool with soft brushes was used at the lowest intensity. To remove the CaCO_3 , distilled water was applied locally with a cotton swab ([Attachment C](#)).



Fig. 6.26 Ewer cleaned with CaCO_3 and Dremel®, with Melinex in between the filigree and glass to protect it from abrasion

For the cleaning of the glass, considering that one of them still had residues of wine, we have decided to not clean the residues, also bearing in mind that they are materials that attest the use of the objects within the church. However, where the glass had dark residues, potentially being dirt, a mixture of 1:1 water and acetone on cotton swabs was used [\[102\]](#).

CONCLUSION

7.1 Summary of findings

Throughout the present master thesis we were able to explore the material history, degradation and conservation challenges of utilitarian silver alloy objects, focusing on ecclesiastical pieces from Malta. The thesis integrated the theoretical frameworks of silver alloy corrosion and mechanical degradation, ethical consideration in the conservation of utilitarian objects and historical insights with exams and analysis of three real case studies of ecclesiastical silver alloy utilitarian objects subjected to Malta's Mediterranean environmental conditions indoor, but influenced by outdoor, with the intent to evaluate and observe use and wear patterns, environmental exposure, historical repairs, and past restoration interventions, and how they influenced the long-term preservation of such objects.

The key findings from this research are:

- From the study of the manufacturing techniques we observed the use of cold-working techniques such as *repoussé* and chasing on the lamp, which likely induced internal stress, increasing susceptibility to SCC.

- The stereomicroscopic exams of the cruets revealed micro-cracks in the filigree. These were likely caused by residual stresses from twisting the wires and cold-working, possibly combined with insufficient annealing.

- For the elemental composition, XRF analysis identified a silver-copper alloy composition. The observed corrosion colours ranged from yellow, orange, red, violet, blue and dark grey, aligning with known corrosion colours in sterling silver reported by several authors.

- Sulfur was detected in multiple areas, indicating sulfur-based corrosion products typical for indoor museum environments. Since the objects were cleaned and conserved after their cessation of use and before being stored within the museum indoors, it is likely that earlier corrosion products, possibly Cl based—formed during their use in churches with open doors and exposure to Malta’s outdoor environmental conditions, with high humidity, sea salt aerosols exposure and the predominance of PM as major pollutant—were removed during the cleaning process.

- The use was observed through surface scratches, missing fragments, and structural cracks which reflected the extensive use of the pieces.

- Cracks likely resulted from a combination of material susceptibility, manufacturing-induced stress, fluctuating environmental conditions within the church, and the extensive active use of the pieces that subjected them to external stress.

- Repairs performed during the active use of the objects shown us that they prioritized utility over aesthetics.

- Repair solders on the cruets had a rough appearance, visually distinguishable from original manufacturing solders which were blending with the filigree.

- Silver patches on the lamp varied in decoration and shape, indicating multiple repair phases and possible use of recycled materials for the chased and stamped ones.

- Zinc was detected in soldered areas, and patches highlighting the use of silver brazing alloys and the preference for hard solders.

- The repairs were structurally stable, not influencing the stability of the pieces, and for this reason they were preserved as material historical evidence of the utilitarian nature of the objects.

- As for the past cleanings of the objects within the laboratory, it was observed the preference of commercial products such as Silver Dip. These products, that have variations in composition and sometimes their composition is not fully disclosed, contain acids and abrasives, which can contribute to surface scratching or etching, loss of fine details, and eventually loss of information.

- The past cleaning practices of silver alloy ecclesiastical objects were mostly driven by aesthetic expectations from church clergy, stakeholders and museum conservators or curators for shiny silver.

7.2 Contribution to the conservation practices

Building on these findings, the study emphasized the importance of preserving material evidence of utilitarian objects, including signs of use, ancient repairs and past restoration and conservation interventions. Rather than removing such features in the favour of aesthetic ideals, conservation strategies seek to interpret and retain them as evidence of the object's functional life and evolving significance.

Highlighting the differences between maintenance practices during an object's active use versus conservation interventions in a laboratory setting, informed us about the evolution of conservation as a practice over time.

The investigation into the various degradation mechanisms affecting utilitarian silver alloy objects, including the atmospheric corrosion in both indoor and outdoor environments, the stress corrosion cracking which can occur in those types of objects, and the mechanical degradations attributed to their extensive use deepened our understanding of how manufacturing techniques, environmental conditions, and use patterns can impact the long-term stability of these objects.

Through this study we were able to conserve and restore the pieces balancing the need to preserve historical material evidence, for example the solders and patches that initially were proposed to be removed because of their aspect, with the aesthetic expectations of museums and stakeholders. However, even in this particular study, the pieces were restored with the same objective proposed by the stakeholders: to regain the original shiny aspect of the silver pieces, which involved the use of abrasives. This represents still an ongoing issue, because the abrasives remove a part of the surface material, potentially eliminating the signs of use. The study demonstrated practical methods for cleaning silver alloy objects, in order to retain important signs of their functional past, using new materials such as the eraser with an organic matrix and abrasive, as well as traditional ones such as calcium carbonate suspended in water, but applying them using different methodologies.

With this thesis, we wanted to raise awareness among collection managers and stakeholders about the importance of preserving signs of use, because they add historical and cultural value to the pieces. There are many ongoing discussions about the cleaning of the objects, the keeping of the patina, which also highlights the time that has passed over the object, but unfortunately the general choice for silver to be shiny still needs to be reconsidered, in order to appreciate and preserve all of the material evidence of the pieces, including their history of use.

7.3 Recommendations for future research

For future work, we would recommend the following:

1. Experimental replication of manufacturing techniques. Those should be done on silver alloy mock-ups using traditional *repoussé* and chasing techniques. To evaluate the mechanical and microstructural degradation induced by such interventions, microscopic examination should be carried out before and after each stage of shaping and decoration to monitor the possible changes, such as the appearance of micro-cracks. Also, those techniques

should be studied with or without final annealing to observe the differences, knowing that SCC can occur in the manufacturing process.

2. Microstructural and elemental analysis via SEM should be employed at multiple stages—prior to and following *repoussé* and chasing—to document any alterations in grain structure, crack development, or localized deformation. SEM is also effective in identifying wear patterns, micro-fractures, and surface degradation at the microscale.

3. Artificial aging in chloride-rich environments. Subjecting the decorated and shaped mock-ups to accelerated artificial aging under chloride-rich conditions to simulate outdoor influenced environmental exposure in areas with high relative humidity, sea salt aerosols and pollution, enabling assessment of corrosion behavior in such conditions. This would provide insight into how the outdoor conditions influence the silver alloy items, and also if the combination of environmental conditions with traditional fabrication methods influence the mechanical alteration of the objects ultimately resulting in SCC.

4. For the identification of the corrosion products XRF analysis should be performed, and for the crystalline phases of the corrosion products that develop on silver alloys, particularly in chloride-containing environments, XRD analysis.

Ultimately, this research contributes broadly to the knowledge of utilitarian silver alloy objects by highlighting the importance of their interpretation through signs of use, repairs, and previous conservation and restoration treatments. Those actions represent key stages in the life cycle of utilitarian objects and are important for proposing informed conservation approach. This study is a modest yet meaningful step toward re-thinking the way in which such objects are perceived and treated in both museum and church settings. By emphasizing the need to preserve not only the material integrity but also the intangible histories of these objects, this study aims to inform and influence the perspectives of curators, conservators, historians, stakeholders, and the wider public about such objects. We should always keep in mind that utilitarian pieces are more than mere decorative objects, they serve as records of their functional and social roles.

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|A

APPENDIX - INVENTORY FOR SPECIAL ITEMS

**A.1 Ewer 53856: Image from the Inventory for special items
when pieces came to the museum**



INVENTORY FOR SPECIAL ITEMS

53856

4950

DEPARTMENT: <u>Museums</u> SECTION: <u>Fine Arts.</u>	DATE REGISTERED	AUTHORITY	REGISTRATION NUMBER <u>PAS/NET/87</u>	CODE NUMBER		
				GROUP	CLASS	DETAIL
DESCRIPTION		DESCRIPTION AUTHENTICATED			COST PRICE (Actual/Estimated)	
ITEM <u>Metal Object</u> <u>Holy Mass Glass Ewer encased in elaborate filigree-wire cover</u>		BY (Signature of Government appointed Expert)			DATE OF INSPECTION	
AUTHOR <u>Unmarked, probably Mathias</u>	LOCATION OF ITEM <u>Mus. of Fine Arts Rm 15 (showcase)</u>	DATE OF TRANSFER	AUTHORITY	SIGNATURE OF OFFICER IN CHARGE		
SUBJECT <u>Holy Mass Ewer</u>						
MEDIUM <u>Silver Filigree</u>						
DIMENSIONS <u>21 cms tall</u>						
PROVENANCE <u>Mrs. Pannis Bequest.</u>						
PUBLISHED/EXHIBITED						
RESTORED						

No. 4950
 Cont. Sheet No.
 Initials of Sheet Control Officer

**A.2 Ewer 53857: Image from the Inventory for special items
when pieces came to the museum**



INVENTORY FOR SPECIAL ITEMS


53857

4452

DEPARTMENT: <u>Museums</u>		DATE REGISTERED	AUTHORITY	REGISTRATION NUMBER <u>FAS/MET/88</u>	CODE NUMBER		
SECTION: <u>Fine Arts</u>					GROUP	CLASS	DETAIL
DESCRIPTION		DESCRIPTION AUTHENTICATED			COST PRICE (Actual/Estimated)		
ITEM <u>Metal Object.</u> <u>Holy Mass Glass Ewer encased in an elaborate filigree-work cover.</u>		BY			(Signature of Government appointed Expert)		
		DATE OF INSPECTION					
AUTHOR <u>Unmarked, probably Maltese</u>		LOCATION OF ITEM	DATE OF TRANSFER	AUTHORITY	SIGNATURE OF OFFICER IN CHARGE		
SUBJECT <u>Holy Mass Ewer</u>		<u>Nus. of Fine Arts</u>					
MEDIUM <u>Silver Filigree</u>		<u>Rm 15</u>					
DIMENSIONS <u>21 cms tall</u>		<u>(Showcase)</u>					
PROVENANCE <u>Prof. Parris Bequest.</u>							
PUBLISHED/EXHIBITED							
RESTORED							

No. 4952
 Cont. Sheet No.
 Initials of Sheet Control Officer

A.3 Ecclesiastical lamp 53871: Image from the Inventory for special when the piece came to the museum (date 1991)

REMARKS	PHOTOGRAPH (to be signed by expert and attached below)
<p>- Inscribed: "un lampien fatto per carita' A.D. 1715"</p> <p>- Damaged & badly repaired in Hz. part (22 30/1/91)</p> <p>- Marks: "H.A eight pointed Cross surmounted by a Crown P.A"</p>	

INVENTORY FOR SPECIAL ITEM

53871

5970





DEPARTMENT: <u>Museums</u>		DATE REGISTERED	AUTHORITY	REGISTRATION NUMBER	CODE NUMBER		
SECTION: <u>Fine Arts</u>				<u>FAS/HCT/2</u>	GROUP	CLASS	DETAIL
DESCRIPTION		DESCRIPTION AUTHENTICATED			COST PRICE (Actual/Estimated)		
ITEM <u>Silver oil lamp complete with chains & cap.</u>		BY <u>J. P. P. P.</u> (Signature of Government appointed Expert)					
		DATE OF INSPECTION <u>21 May 1991</u>					
AUTHOR <u>Maltese 18th cent. (dtd. 1715)</u>		LOCATION OF ITEM	DATE OF TRANSFER	AUTHORITY	SIGNATURE OF OFFICER IN CHARGE		
SUBJECT <u>Oil lamp has coat of arms of C. G. P. P. and engraved figure of St. Philip Neri. Inscribed (see sketch).</u>		<u>Mus. of Fine Arts Rm 25</u>	<u>21. 11. 2002</u>	<u>D. I. P. P.</u>	<u>[Signature]</u>		
MEDIUM <u>Silver</u>							
DIMENSIONS <u>height: 22cms</u> <u>width of rim: 20cms.</u>							
PROVENANCE <u>Church of Our Lady of Victories Valletta</u>							
PUBLISHED/EXHIBITED							
RESTORED							








Cont. Sheet No. Initials of Sheet Control Officer







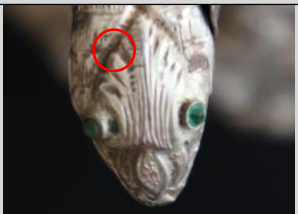
5970


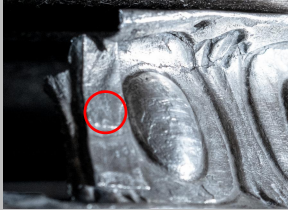





No. 5970







APPENDIX - XRF ANALYSIS RESULTS

Object	Analyzed area	Picture with the analyzed area	XRF key elements
Ewer 53857	Base metal		Ag, Cu
	Solder		Ag, Cu, S
	Solder		Ag, Cu, Zn, S, Ca
	Base material		Ag, Cu, S

	Solder		Ag, Cu
	Corrosion		Ag, Cu, S
	Cap base metal		Ag, Cu, Zn
	Cap flower metal		Ag, Cu, S
Ewer 53856	Base material		Ag, Cu, S
	Solder		Ag, Cu, S
	Solder		Ag, Cu, Zn

	Base material		Ag, Cu
	Solder		Ag, Cu, S
	Base material		Ag, Cu, Zn, S
	Corrosion		Ag, Cu, S
	Cap base material		Ag, Cu, S
	Cap flower metal		Ag, Cu
	Snake head		Ag, Cu, Au, S

	Snake head inside		Ag, Cu, Fe, Pb, As, Ca
Ecclesiastical lamp	Patch		Ag, Cu, Zn, S
	Patch		Ag, Cu, Zn, S
	Patch		Ag, Cu
	Patch		Ag, Cu, Zn
	Patch		Ag, Cu
	Base material		Ag, Cu

	Metal detachment		Ag, Cu
	Material deposit		Ag, Cu, Al, S, Si
	Cap loop		Cu, Ca
	Chain link		Ag, Cu, Zn
	Chain link yellow		Ag, Cu, Zn
	Chain link solder		Ag, Cu, Zn

APPENDIX - OBJECTS BEFORE AND AFTER CLEANING

Before cleaning:

After cleaning:



Ewer 53856



Ewer 53857



Ewer 53856



Ewer 53857

Before cleaning:



After cleaning:





2025 Alexandra Maria Ioaneş

From Use to Museum: A Comprehensive Investigation of Maintenance, Conservation and Restoration
Practices for Utilitarian Silver Alloy Objects