

# Conservation and restoration of metals

For silver objects, see conservation and restoration of silver objects. For iron and steel objects, see Conservation and restoration of iron and steel objects. For copper-based objects, see Conservation and restoration of copper-based objects. For outdoor bronze objects, see Conservation and restoration of outdoor bronze objects.

**Conservation and restoration of metals** is the activ-



*Derveni krater, bronze, 350 BC, height: 90.5 cm (35 1/2 in.), Inv. B1, Archaeological Museum of Thessaloniki, after cleaning and conservation.*

ity devoted to the protection and preservation of historical (religious, artistic, technical and ethnographic) and archaeological objects made partly or entirely of metal. In it are included all activities aimed at preventing or slowing deterioration of items, as well as improving accessibility and readability of them as objects of cultural heritage. Despite the fact that metals are generally considered as the relatively permanent and stable materials, in contact with the environment they deteriorate gradually, some faster and some much slower. This applies especially to archaeological finds.

It is very important that a conservator of metals has knowledge of basic metalworking techniques, history of metalwork, history of art, archaeology, corrosion of metals, scientific research methods, theory and ethics of conservation-restoration.

## 1 Metals and alloys commonly used for cultural heritage objects



*The bronze apoxyomenos, dated to between the 1st and 2nd century BC, found and recovered from Adriatic sea near the small island Vele Oryule, near island Loshiny, Croatia; example of archaeological metals conservation.*

- Gold
- Silver
- Copper
- Bronze
- Brass
- Nickel
- Nickel silver
- Monel
- Chromium
- Iron and Steel
- Weathering steel (Corten)

- Stainless steel
- Titanium
- Tin and Pewter
- Lead
- Zinc
- Aluminium

## 2 Metals and alloys less commonly used for cultural heritage objects

- Antimony
- Magnesium
- Niobium
- Palladium
- Platinum
- Rhodium
- Mercury
- Electrum
- Tumbaga
- Shakudo
- Shibuichi
- Bidri
- Hepatizon

## 3 Metalworking techniques

### 3.1 Basic techniques

- Casting
- Forging
- Folding
- Sawing
- Cutting
- Bending
- Drilling
- Filing (metalworking)
- Piercing
- Sanding
- Polishing

### 3.2 Joining techniques

- Soldering
- Welding
- Mechanical joining
- Gluing/cementing

### 3.3 Some supplementary techniques

- Repousse
- Chasing
- Raising (metalwork)
- Metal spinning
- Annealing (metallurgy)

### 3.4 Surface decoration techniques

- Enamelling
- Niello
- Engraving
- Etching
- Granulation
- Filigree
- Inlay (Damascening)
- Mokume gane
- Pattern welding
- Plating
- Chemical coloring of metals (Patination)
- Heat coloring
- Combining metals and other materials

### 3.5 Some contemporary techniques

- Electroforming
- Reticulation
- Anodizing
- Photoetching



Perseus with the Head of Medusa in the Loggia dei Lanzi gallery on the edge of the Piazza della Signoria in Florence; picture taken after the statue's cleaning and restoration.

## 4 Deterioration of metals

An essential cause of deterioration is corrosion of metal objects or object deterioration by interaction with the environment. As the most influential factors of deterioration of historical objects should be pointed out as the relative humidity and air pollution while in archaeological objects a crucial role has composition, depth, humidity and amount of gasses in the soil. In cases of marine or fresh water finds the most important factors of decay are the amount and composition of soluble salts, water depth, amount of dissolved gases, the direction of water currents and the role of both microscopic and macroscopic living organisms.<sup>[2]</sup>

## 5 Deterioration of materials associated with metals

Associated materials deteriorate depending on the origin whether they are organic or inorganic materials. Organic materials usually fail in a relatively short period of time, primarily due to biodegradation. With inorganic materials are these processes considerably longer and more complex. Amount of gases, humidity, depth and composition of soil are very important. In case of salty and sweet water finds essential are amount of gases dissolved in water, depth of water, direction of currents, and mi-

croscopic and macroscopic living organisms.

## 5.1 Organic materials

- Leather
- Wood
- Paper
- Fur
- Feathers
- Textile
- Bone
- Horn
- Tortoiseshell
- Amber
- Plant fiber
- Shell
- Pearls
- Ivory
- Coral
- Jet (lignite)

## 5.2 Inorganic materials

- Precious and semiprecious stones (Gemstone)
- Glass
- Enamel
- Niello
- Ceramics
- Porcelain
- Plastics

## 6 Metals conservation planning

### 6.1 Basics

As with the conservation and restoration works on any other material, here are the basic tenets of conservation-restoration based on the quality of execution and the best possible preservation of cultural, historical and technological identity and integrity of objects. Minimal intervention, reversibility and repeatability of preferred treatment are essential, as well as the possibility of easy identification of restored parts.<sup>[3]</sup> Recently non-toxic nature of

used materials and procedures becomes important too, both in relation to objects and conservator-restorer as a performer, but also in relation to the environment.

## 6.2 Research

Nowadays scientific research is an integral part of the metals conservation treatment, at least in highly developed countries.

### 6.2.1 Identification of metals and alloys

- Simple methods - visual examination, spot tests, specific gravity
- Scientific methods - X-ray fluorescence, XRD, Particle-induced X-ray emission, LIBS, SEM, electrochemical techniques, metallography

### 6.2.2 Identification of corrosion processes and products

- Simple method - visual examination, spot tests
- The Oddy test - for copper, silver, and lead
- Scientific methods - xrd, SEM, metallography

### 6.2.3 Identification of materials associated with metals

- Simple methods - visual examination, spot tests, specific gravity
- Scientific methods - xrf, chromatography,

Raman spectroscopy

### 6.2.4 Identification of technology used to produce objects

- Simple methods - visual examination
- Scientific methods - metallography, x-ray radiography, x-ray computed tomography

## 6.3 Decision making

In preparing the strategy of the metals conservation project interdisciplinary approach to the same is essential. It implies the participation of as many experts as is possible, as a minimum, we can take curator (archaeologist, historian, art historian), scientists specialized for corrosion of metallic objects of cultural heritage and the conservator - restorer.

## 6.4 Documentation

Systematic and well-managed documentation is today an essential prerequisite for quality executed conservation and restoration treatments, including documentation of the state of objects before, during and after treatment. Identification of materials and procedures used to produce object and the results of any scientific research must be part of documentation too. Last but not least- an integral part of the documentation must be a recommendation for further care of object.

## 6.5 Ethics and ethical problems in metals conservation

The ethical concept of conservation of metal objects in principle is the same as those in other fields of conservation-restoration of cultural heritage.

But there are several specific problems that can only be found in the conservation of metals - problem of heat treatment of archaeological objects, and the problem of radical restoration of historic, mostly technical, but also architectonic objects too.

While in the first case problem is primarily in the destruction of valuable scientific data, in case of the technical, the architectural, and somewhat less often, historical objects problem is that a radically restored items just simulate the original appearance of the object, and so in some ways that objects can be considered even as, more or less successful fakes, which only superficially simulate long-lost or never existing state of object.

According to the above-mentioned, whenever it is possible real historical substance must be preserved. Thoroughly documented and technically professionally executed restoration of objects, must be avoided because such objects must be seen only as freshly painted surrogates of authentic historic substance.

Ethical problems connected with conservation of sacred metallic heritage objects can be included too.<sup>[4]</sup>

# 7 Conservation

## 7.1 Preventive conservation

Main article: Collections care

Metallic heritage objects are sensitive to environmental conditions such as temperature, humidity, air pollution and exposure to light and ultraviolet light. They must be protected in a controlled environment where such variables are maintained within a range of damage-limiting levels.

Preventive conservation, also known as collections care,

is an important element of museum policy. It is an essential responsibility of members of the museum profession to create and maintain a protective environment for the collections in their care, whether in store, on display, or in transit. A museum should carefully monitor the condition of collections to determine when an artifact requires conservation work and the services of a qualified conservator.

## 7.2 **Interventive conservation**

### 7.2.1 **Cleaning**



*Conservation of gilt bronze Horses of Saint Mark, (Venice).*

The most common procedure in conservation and restoration of metals is the cleaning process. This process can be distinguished between mechanical, chemical, electrochemical, ultrasonic, plasma and laser cleaning. In principle, it is aimed at removing dirt and corrosion products from the surface of a metal object. In many cases archaeology objects only can be cleaned mechanically.

### 7.2.2 **Structural consolidation**

Aimed at strengthening of the physical structure of the object, and correcting the shape of the object.

- Mechanical joining - riveting / tab and slot / overlapping / screws
- Soldering - soft / hard
- Welding - oxyacetylene / electric arc / TIG / tack / laser
- Gluing/Cementing
- Reconstructions -in original material - in polymers - \*3D printing<sup>[28]</sup>

### 7.2.3 **Reconstruction of missing parts or surface decoration**

In certain cases, metals conservator must re-create the lost parts of objects or restore original surface decoration. This approach is accurate only if we have an exact documentation or photographs of items in a complete, currently non-existent state that we want to return.

New parts must be clearly and visibly marked and at least they must be minimally different from the original historic material.

If needed, those parts must be easily and completely removable from the object, and with methods which will not harm it.

Only cyanide or hexchromate free processes must be used.

Only worn-out spots can be replated.

Replating of entire object must be avoided.

### 7.2.4 **Stabilization**

Focused on slowing of deterioration of objects - in case of archaeology objects the thorough removal or blocking of chloride salts. In case of the historical objects it is focused on the use of corrosion inhibitors, conversion coatings, rust converters or eventually oxygen free storage.

- Chloride removal (chemical processes, electrochemical processes)
- Corrosion inhibitors (benzotriazole, tannin)
- Rust converters
- Conversion coatings (phosphate conversion coatings, phosphate/tannin, etc.)
- Oxygen free storage

### 7.2.5 **Protective Coatings**

Still mainly focused on use of clear coats and waxes, in case of technology objects oil coatings can be used too. In general it supports the stabilization process.<sup>[55]</sup>

- Clear coats:

#### **Paraloid B-72**

For Additional information on Paraloid B-72, see Paraloid B-72.

durable and non yellowing acrylic resin, chemically an ethyl methacrylate copolymer. It can be used for conservation of metals. Soluble in acetone, toluene, xylene,

Shell Cyclo Sol® 100/Shell Cyclo Sol® 53, Arcosolv® PM/1-Methoxy-2-propanol.<sup>[56]</sup>

#### **Paraloid B 67**

is acrylic resin, chemically it is an isobutyl methacrylate polymer. Soluble in toluene, xylene, acetone, Shell Cyclo Sol® 100/Shell Cyclo Sol® 53, Arcosolv® PM/1-Methoxy-2-propanol and white spirit acetone mixture (90 parts white spirit/10 parts acetone).<sup>[57]</sup>

#### **Paraloid B 44**

is acrylic resin, chemically it is composed of methyl methacrylate and ethyl acrylate copolymer. Soluble in toluene, xylene, acetone. It is used for paints and clear coating for metals. It is ingredient in Inralac metal coating.<sup>[58]</sup>

#### **Paraloid B 48 N**

is acrylic resin, chemically it is copolymer of methyl methacrylate and butyl acrylate. It is used as a clear coating for metals - copper, brass, bronze, and zinc. Soluble in toluene, xylene, methyl ethyl ketone, and acetone<sup>[59]</sup>

#### **Inralac**

is special proprietary clear coat for copper and its alloys. It is based on Paraloid B 44 acrylic resin dissolved in toluene. It contains benzotriazole as copper corrosion inhibitor too.<sup>[60]</sup>

#### **Nitrocellulose lacquer**

is solvent based lacquer that contain nitrocellulose, a resin obtained from the nitration of cotton and other cellulosic materials.<sup>[61]</sup> Can be used on silver objects. Frigilene, Agateen No.27 and Perlitol RE 1260 are good brands.

#### **ORMOCER**

Organically modified ceramic, also known as ORMOCER (ORganically MODified CERamic) is a type of coating used in the conservation of metals. ORMOCER was originally developed by the Fraunhofer Society for the Advancement of Applied Research in Munich. While it is still in research phase, ORMOCER is essentially a heteropolysiloxane-based clear coat.<sup>[62]</sup>

#### **Other used varnishes or lacquers that would be worthwhile to examine:**

Pantarol A (German product), the use of it is mentioned in German literature, according to manufacturer it is special acrylic coating for metal<sup>[63]</sup>

Everbrite ProtectaClear Coating, Everbrite Coating (USA products) - worthwhile to be tested, according to manufacturer product is easily removable from treated objects<sup>[64] [65]</sup>

- Waxes:

#### **Renaissance Wax**

**Main article: Renaissance Wax**

is a brand of microcrystalline wax polish that is widely encountered in antique restoration and museum curation. Although not appropriate for all materials, it is known to and used by almost every collection. It is also used as a primary finish for cabinetry and furniture. Renaissance wax is also used by reenactors of historic swordsmanship to protect armour and weapons. It is widely recognised that this substance is more protective and longer lasting than oil, especially for swords and helmets that are frequently touched by human hands.

To quote a typical commercial supplier of conservation materials, it is used, to revive and protect valuable furniture, leather, paintings, metals, marble, onyx, ivory etc. Freshens colours and imparts a soft sheen<sup>[66]</sup>

#### **Cosmolloid 80 H**

is refined white microcrystalline wax. It can be used on historical and archaeological metals. Melting point 60–94 °C. Soluble in benzol, ether, chloroform, carbon disulfide, carbon tetrachloride, turpentine, petroleum distillates, and fixed oils; partially soluble in acetone, diacetone alcohol. Main ingredient in Renaissance Wax.

#### **Dinitrol 4010**

is a long-term engine protection proprietary product with heat resistance up to 200 °C. It leaves a firm transparent film with short drying time and good adhesion and flexibility on all metal surfaces, rubber and plastic parts. Dinitrol 4010 is resistant to alkali and acidic solutions. According to some research articles it can be used on metallic heritage objects too<sup>[67]</sup>

#### **Poligen ES 91 009**

is patented wax emulsion (BASF), according to some sources better than Paraloid B 72<sup>[68]</sup>

- Oils

-WD 40 / Ballistol / 80 parts white spirit+20 parts fish oil

- Combinations

-base coat Paraloid B 72 / topcoat Renaissance Wax etc.

### **7.3 Conservation of materials associated with metals**

#### **7.3.1 Precious and semi precious stones**

In principle do not use any solvent, but only distilled water, or a 10% solution of soapwort plant (*Saponaria officinalis*). You must be Especially careful when working on porous gemstones like malachite, opal, chalcedony, chrysoptase, agate, carnelian, lapis lazuli, jade and turquoise. Special attention requires gemstones combined with colored metal foils, in this case, the liquid does not come into contact with the foil. Do not use ultrasonic cleaning.

### 7.3.2 Enamels

Main article: Conservation and restoration of glass objects

### 7.3.3 Niello

Nielloed items can be cleaned only mechanically, never try to use chemical cleaning. Black pigment mixed with Paraloid B 72 can be used for reconstruction of missing parts. Concentrated solution of Paraloid B 72 or B 67 (soluble in white spirit) can be used as reversible glue.

### 7.3.4 Amber

Do not clean with solvents, do not use ultrasound, you can use only distilled water, or a mixture of water and ethanol (add up to 0.5% crosslinker).<sup>[69]</sup> Variety of waxy resin mixtures can be used as glue, depending on the color of amber. You can use 10% solution of Canada balsam in toluene.<sup>[70]</sup> Archaeological material can be cleaned only mechanically. Soaking in liquid paraffin can be used to consolidate and improve color of amber.<sup>[71]</sup> According to one Korean article for consolidation can be used Paraloid B 67 dissolved in xylene (proved more stable than white spirit, usual solvent for B 67)<sup>[72]</sup> Artifacts must be Protected from strong light and high temperatures, low humidity and oscillations in humidity, in the case of metal/amber objects do not to use corrosion inhibitors.<sup>[73]</sup>

### 7.3.5 Oriental lacquer - urushi

Requires a completely different approach than western lacquers. May be found on the Japanese arms and armour. The best approach – leave it to expert for oriental lacquer.<sup>[74][75][76]</sup> Mixture of 6-8% polyvinyl alcohol and chalk can be used as filling material (Rhoplex WS 24 can be used too).<sup>[77]</sup> Japanese conservators use traditional techniques, but as Urushi causes allergic reactions, these methods are not recommended. Clean it with an aliphatic hydrocarbon such as white or mineral spirits. Distilled water or saliva (moistened cottonwool swabs) can caused discoloration and should be avoided by the inexperienced: pH is crucial. Keep objects in rooms with controlled humidity and temperature, preferably about 50% RH, and protect them from UV radiation.

### 7.3.6 Coral

Can be cleaned with cotton wool swabs soaked in distilled water, or with a mixture of distilled water and ethanol.<sup>[78]</sup> Do not use ultrasound. Avoid any contact with acids.

### 7.3.7 Pearls

Historical objects can be cleaned using a mixture of 70% ethanol and 30% weak ammonia water (1%). To remove the surface layer that has lost luster you can use 3-5% EDTA, after that step rinse with distilled water, and then with 80% ethanol, then with 90% ethanol, and finally with pure ethanol.<sup>[79]</sup> Do not use ultrasound. Archaeological finds must be treated as soon as possible, preferably after excavation, you can clean them only mechanically, then consolidate with 2% Paraloid B 72, in the case of dry findings (first saturate with solvent in which it is dissolved), in case of damp or wet findings use Rhoplex WS 24 (acrylic dispersion).<sup>[80]</sup> Somewhat More recent Russian literature recommends use of bleached beeswax dissolved in white spirit or medical benzine as protective coating. Fish glue mixed with water and alcohol (7/3), with addition of 1% katamine AB as biocide can be used as glue. Nonionogenic detergent 2-3% in a mixture of water and alcohol can be used for cleaning.<sup>[81]</sup> Avoid prolonged contact with water, sudden changes in temperature and relative humidity, including strong light or contact with acidic or alkaline solutions (soap water too).

### 7.3.8 Mother of pearl

### 7.3.9 Ivory, bone and antler

Main article: Conservation and restoration of ivory objects

### 7.3.10 Tortoiseshell

### 7.3.11 Jet

You can clean it with cottonwool swabs soaked in distilled water or soapwort extract (*Saponaria officinalis*, 100 grams of dried root per 1 liter of boiling water). Archaeological material can be cleaned only mechanically. Wax/resin mixtures or concentrated solution of Paraloid B 72 (or B 67) can used as glue for archaeology objects.<sup>[82]</sup>

### 7.3.12 Wood

### 7.3.13 Textile

Main article: Textile preservation

### 7.3.14 Paper

### 7.3.15 Glass

Main article Conservation and restoration of glass objects

### 7.3.16 Ceramics and porcelain

Main article: Conservation and restoration of ceramic objects

### 7.3.17 Leather

### 7.3.18 Plastics

Main article: Conservation and restoration of objects made from plastics

### 7.3.19 Wax

### 7.3.20 Plaster

Unsealed plaster can be cleaned with soft brush only; never try to use water or water-based cleaning solutions. Sealed plaster can be cleaned with a swab dampened with water or white spirit.<sup>[83]</sup>

## 8 Replicas and Copies

- molding (process)
- casting
- electroforming
- 3D printing<sup>[84]</sup>

## 9 Storage of metallic heritage objects

The items should be stored in rooms that are protected from polluted air, dust, ultraviolet radiation, and excessive relative humidity - ideal values are temperature of 16-20 °C and up to 40% (35-55% according to recent Canadian Conservation Institute recommendations) relative humidity, noting that if metal is combined with organic materials, relative humidity should not be below 45%. Archaeological objects must be stored in rooms (or plastic boxes) with very low relative humidity, or in the case of particularly valuable items in the chambers with nitrogen or argon. Copper or copper alloy objects with active corrosion up to 35% RH. Iron objects with active corrosion 12-15% RH. Shelves in the storerooms must be of stainless steel or chlorine and acetate free plastic or powder coated steel. Wood and wood based products (Particle board, plywood) must be avoided. Also do not use rubber, felt or wool. When you are handling metal objects, always wear clean cotton gloves. Lighting levels

must be kept below 300 lux (up to 150 lux in case of lacquered or painted objects, up to 50 lux in case of objects with light sensitive materials)<sup>[85]</sup>

## 10 History of metals conservation

### 10.1 Important persons

- Gustav Rosenberg
- William Matthew Flinders Petrie
- Friedrich Rathgen
- Alexander Scott
- Harold Plenderleith
- Mstislav Vladimirovich Farmakovskiy
- Albert France-Lanord
- Robert M. Organ
- Hanna Jedrzejewska
- Joachim Szvetnik

## 11 Specializations within the profession

- Conservation of Historical Metal Objects
- Conservation of Archaeological Metal Objects
- Conservation of Technological Metal Objects
- Conservation of Ethnographic Metal Objects
- Conservation of Architectural Metal Objects
- Conservation of Metal Sculpture
- Conservation of Gold and Silversmiths Works
- Conservation of Arms and Armour

## 12 Training

Main article: conservation-restoration training

### 12.1 USA

- Buffalo State College, Art Conservation Department, objects specialization
- UCLA/Getty Masters Program - Conservation of Archaeological and Ethnographic Materials
- Winterthur/University of Delaware Program in Art Conservation, objects specialization



## 12.2 Canada

- Queens University, Art Conservation, objects specialization
- Fleming College, Collections Conservation and Management

## 12.3 Mexico

- Escuela nacional de conservacion, restauracion y museografia, Ciudad de Mexico, Diplomado de Especialización en Patrimonio Metálico

## 12.4 South America

- Chile

Centro Nacional de Conservacion y Restauracion, Santiago de Chile, objetos arqueológicos, etnográficos e históricos

- Perú

Universidad Nacional Mayor de San Marcos, Escuela academico profesional de Conservación y Restauración

- Brasil

Universidade Federal de Pelotas, Instituto de Ciências Humanas, Laboratório Multidisciplinar de Investigação Arqueológica (LÂMINA)

## 12.5 Africa

- Egypt

Conservation Department, Faculty of Archaeology, Cairo University

- South Africa

The South African Institute for Objects Conservation, Joubertina, Eastern Cape, metals conservation

## 12.6 Australia

The University of Melbourne, Centre for Cultural Materials Conservation

## 12.7 Europe

- Austria

Universitaet fuer Angewandte Kunst, Wien, Konservierung/Restaurierung von Objekten

- Belgium

Koninklijke Academie voor schone kunsten, Antwerpen, metalen conservatie

- Croatia

1. Sveučilište u Dubrovniku, konzervacija restauracija metala (BA+MA)

2. Umjetnička akademija u Splitu, Konzervacija restauracija metala (BA+MA)

- Denmark

The Royal Danish Academy of Fine Arts, School of Conservation

- Czech Republic

Konzervování-restaurování uměleckořemeslných děl z kovů, Turnov

- France

1. Université Panthéon-Sorbonne Paris I, Paris, Conservation and restoration department

2. Institut de Formation des Restaurateurs d'Oeuvres d'Art ,Institut National du Patrimoine, Saint-Denis-la-Plaine, Metals conservation

- Finland

Metropolia University of Applied Sciences, Helsinki, objects conservation

- Germany

1. Roemisch Germanisches Zentralmuseum, Mainz, Ausbildung zum Restaurator des Fachbereichs Archeologie

2. Hochschule fuer Technik und Wirtschaft, Berlin, schwerpunkt Archaeologisch-Historisches Kulturgut

3. Staatliche Akademie der Bildende Kuenste, Stuttgart, Objekt Restaurierung

4. Fachhochschule Potsdam, Metallkonservierung

5. University of Applied Sciences Erfurt, Archäologisches Kulturgut und kunsthandwerkliche Objekte

- Greece

Technological Educational Institution (TEI), Athens

- Hungary

Hungarian Academy of Fine Arts, Budapest, conservation of metalwork and goldsmiths works

- Italy

1. Istituto Superiore per la Conservazione e il Restauro, Roma

2. Opificio delle Pietre Dure, Firenze

- Netherlands

Universiteit van Amsterdam, Amsterdam, MA metaal-restauratie

- Poland

Nicolaus Copernicus University in Torun, Institute of Fine Art, Department of Conservation and Restoration of Historic and Artistic Works, graduate program, metal conservation

- Portugal

Faculdade de Ciências e Tecnologia da Universidade Nova, Lisboa

- United Kingdom

1. West Dean College, metalwork conservation
2. University of Sussex, metalwork conservation

- Spain

1. Universidad de Granada, Grado en conservación y restauración de bienes culturales
2. Escuela Superior de Conservación y Restauración de Bienes Culturales, Madrid, Especialidad de bienes arqueológicos
3. Escuela Superior de Conservación y Restauración de Bienes Culturales, Barcelona, Especialidad de bienes arqueológicos
4. Escuela Superior de Conservación y Restauración de Bienes Culturales, Pontevedra, Especialidad de bienes arqueológicos

- Switzerland

La Chaux de Fonds, Haute Ecole de Conservation-restauration Arc, objects conservation

## 12.8 Ukraine

Lviv Academy of Arts, metals conservation

## 12.9 Russian Federation

- Факультет искусства реставрации Московской государственной художественно-промышленной академии им.С. Г. Строганова, Moscow-katedra"Restavraciya hudozhestvennogo metalla" (Conservation of artistic metalwork)

## 12.10 India

NATIONAL MUSEUM INSTITUTE of History of Art, Conservation and Museology (Deemed to be University) Ministry of Culture, Government of India, New Delhi

## 12.11 Iran

1. Art University of Isfahan, Faculty of Conservation, Department for Conservation of Art Objects
2. Tabriz Islamic Art University, Conservation Department

## 12.12 Pakistan

Hazara University, Mansehra

## 12.13 Qatar

University College London, in partnership with Qatar Foundation and Qatar Museums Authority, Doha, objects conservation

## 12.14 Turkey

Gazi University, Faculty of Fine Arts, Ankara, conservation department

# 13 Further reading

## 13.1 Essential literature

1. Corrosion and metal artifacts : a dialogue between conservators and archaeologists and corrosion scientists, Washington 1977.(online)
2. Conservation & restoration of metals : proceedings of the symposium held in Edinburgh, 30–31 March 1979., Edinburgh 1979.

3. Stambolov, T. The corrosion and conservation of metallic antiquities and works of art - a preliminary survey, Amsterdam 1985.
4. Corrosion inhibitors in conservation: The Proceedings of the conference held by UKIC in association with the Museum of London, London 1985.
5. Pearson, C. Conservation of Marine Archaeological Objects, London 1987.
6. Conservation of metal statuary and architectural decoration in open-air exposure : symposium, Paris, 6. - 8. X. 1986 = Conservation des oeuvres d'art et décorations en métal exposées en plein air, Rome 1987.
7. Townsend, J.H.; Child, R.E. Modern metals in museums, Cardiff 1988.
8. Metals Conservation: 7th International Restorer Seminar, Veszprem, Veszprem 1989.
9. METAL 95, Proceedings of International Conference on Metal Conservation, London 1997.
10. METAL 98, Proceedings of International Conference on Metal Conservation, London 1999.
11. METAL 01, Proceedings of International Conference on Metal Conservation, Perth 2002.
12. METAL 04, Proceedings of International Conference on Metal Conservation, Canberra 2005.(online)
13. METAL 07, Proceedings of International Conference on Metal Conservation, Amsterdam 2007.
14. METAL 2010, Proceedings of International Conference on Metal Conservation, Charleston 2011.
15. Scott, D.A. Metallography and Microstructure of Ancient and Historic Metals, Santa Monica 1991.(online)
16. Scott, D.A. Ancient and Historic Metals-Conservation and Scientific Research, Santa Monica 1994.(online)
17. Scott, D.A. Copper and Bronze in Art-Corrosion, Colorants, Conservation, Los Angeles 2002.
18. Scott, D.A. Iron and Steel in Art-Corrosion, Colorants, Conservation, London 2009.
19. Scott, D. A. Ancient Metals: Microstructure and Metallurgy Volume I, Los Angeles 2011.
20. Scott, D. A. Gold and Platinum Metallurgy of Ancient Colombia and Ecuador.: Ancient Metals: Microstructure and Metallurgy Volume II, Los Angeles 2012.
21. Scott, D. A. ANCIENT METALS: MICROSTRUCTURE AND METALLURGY Volume III CATALOGUE OF ANCIENT COLOMBIAN DATA., Los Angeles 2012.
22. Scott, D. A. Ancient Metals: Microstructure and Metallurgy Vol. IV: Iron and Steel., Los Angeles 2013.
23. Selwyn, L. Metals and Corrosion-A Handbook for Conservation Professional, Ottawa 2004.
24. Draymann-Weiser, T. Gilded Metals-History, Technology, Conservation, London 2000.
25. Draymann-Weiser, T. Dialogue/89 - The conservation of bronze sculpture in the outdoor environment : a dialogue among conservators, curators, environmental scientists, and corrosion engineers, Houston 1992.
26. Dillman, P.; Beranger, G.; Piccardo, P.; Matthiesen, H. Corrosion of metallic heritage artefacts- Investigation, Conservation and Prediction of long term behaviour, Cambridge 2007.
27. Cronyn, J.M. The Elements of Archaeological Conservation, London 1990.
28. Rodgers, B. The Archaeologist Manual for Conservation-A Guide to Non-toxic, Minimal Intervention Artifact Stabilization, New York 2004.
29. Stuart, B. Analytical Techniques in Materials Conservation, Chichester 2007.
30. May, E.; Jones, M. Conservation Science-Heritage Materials, Cambridge 2006.
31. Untracht, O. Metal Techniques for Craftsmen, New York 1968.
32. La Niece, S.; Craddock, P. Metal Plating and Patination: Cultural, Technical and Historical Developments, Boston 1993.
33. Anheuser, K.; Werner, C. (Eds.) Medieval Reliquary Shrines and Precious Metalwork / Châsses-reliquaires et Orfèvrerie Médiévales, London 2006.
34. Horie, C.V. Materials for Conservation, Oxford 2010.
35. Smith, R.D. Make all sure : the conservation and restoration of arms and armour, Leeds 2006.
36. Appelbaum, B. Conservation Treatment Methodology, New York 2007.
37. Practical Building Conservation! Metals and Glass, Farnham 2012.
38. Dillmann, P., Watkinson, D., Angelini, E., Adriaens, A., (Ed.) Corrosion and conservation of cultural heritage metallic artefacts, Cambridge 2013.

39. Risser, E.; Saunders, D. *The Restoration of Ancient Bronzes - Naples and Beyond*, Los Angeles 2013. (online)

### 13.2 Some important books on metal conservation in languages other than English

1. Mourey, W. *La conservation des antiquités métalliques, du chantier de fouilles au musée*, Draguignan 1987.
2. Stambolov, T.; Bleck, R.D.; Eichelmann, N. *Korrosion und Konservierung von Kunst und Kulturgut aus Metall*, Weimar I/1987. (online), II/1988. (online)
3. Шемаханская, М.С. РЕСТАВРАЦИЯ МЕТАЛЛА. Методические рекомендации (1989), Moscow 1989. (online)
4. НИКИТИН, М.К., МЕЛЬНИКОВА, Е.П. ХИМИЯ В РЕСТАВРАЦИИ. СПРАВОЧНОЕ ПОСОБИЕ.; Leningrad 1990 (chapter on metals conservation) (online)
5. Born, H. *Restaurierung Antike Bronzewaffen*, Mainz 1993.
6. Heinrich, P. (Hrsg.) *Metallrestaurierung*, Munich 1994.
7. Catello, C. *Argenti antichi : tecnologia restauro conservazione : rifacimenti e falsificazioni*, Naples 1994.
8. Marabelli, M. *Conservazione e restauro dei metalli d'arte*, Rome 1995.
9. Krause, J. *Sarkofagi cynowe : problematyka technologiczna warsztatowa i konserwatorska*, Torun 1995.
10. Dolcini, L. *Il restauro delle oreficerie: aggiornamenti*, Milan 1996.
11. Mach, M. *Metallrestaurierung/Metal Restoration*, Munich 1997.
12. Fischer, A. *Reste von organischen Materialien an Bodenfunden aus Metall – Identifizierung und Erhaltung für die archäologische Forschung*, Munich 1997.
13. Minzhulin, O.I. *Restavracyia tvoriv z metalu*, Kiev 1998.
14. Anheuser, K. *Im Feuer Vergoldet*, AdR-Schriftenreihe zur Restaurierung und Grabungstechnik, Band 4 / 1998.
15. Mach, M.; Moetner, P. *Zinkguß, die Konservierung von Denkmälern aus Zink*, Munich 1999.
16. Barrandon, J.N.; Meyer-Roudet, H. *A la recherche du métal perdu : nouvelles technologies dans la restauration des métaux archéologiques*, Paris 1999.
17. Meissner, B.; Doktor, A.; Mach, M. *Bronze und Galvanoplastik-Geschichte-Materialanalyse-Restaurierung*, Dresden 2000. (online)
18. Volfovsky, C.; Philippon, J. *La Conservation des métaux*, Paris 2001.
19. Brueggerhoff, S.; Koenigfeld, P. *Farbige Eisengitter der Barockzeit: Beiträge zu Geschichte und Funktion, Korrosion und Konservierung*, Bochum 2002.
20. Melucca Vaccaro, A.; De Palma, G. *I Bronzi di Riace : restauro come conoscenza : 1: archeologia, restauro, conservazione/vol.1*, Roma 2003.
21. Gaomez Moral, F. *Conservacion De Metales De Interes Cultural*, Quito 2004.
22. Letardi, P.; Trentin, I.; Cutugno, G. *Monumenti in bronzo all'aperto. Esperienze di conservazione e confronto.*, Genova 2004.
23. Ronald Gobiet (Ed.), *Die Salzburger Mariensäule - Zur Konservierung monumentaler Bleiplastiken / Sulla conservazione dei monumenti in piombo*, Salzburg 2006.
24. Salvi, A. *Meteo e metalli. Conservazione e restauro delle sculture al aperto. Dal Perseo all arte contemporanea*, Florence 2007.
25. Catello, D. *Il restauro delle opere in argento. Restoration of silver artifacts*, Naples 2008.
26. Schlaepfer, B.R. *Metals: Restauracao e conservacao*, Rio de Janeiro 2009.
27. Barrio, J.; Cano, E. (Editores). *MetalEspaña '08. Congreso de Conservación y Restauración del Patrimonio Metálico*. UAM-CSIC, Madrid 2009.
28. Krist, G. *Metallrestaurierung-Metallkonservierung: Geschichte, Methode und Praxis*, Vienna 2009.
29. Safarzynski, S.; Weker, W. *Wprowadzenie do sztuki konserwacji metalu*, Warsaw 2010.
30. Schmidt-Ott, K. *Das Plasma in der Metallkonservierung-Moeglichkeiten und Grenzen*, Zurich 2010.
31. Bruecke, D. *Die Konservierung pigmentierter Altbeschichtungen auf Stahlbauten*, Saarbrücken 2011.
32. Diaz Martinez, S.; Garcia Alonso, E. *Técnicas metodológicas aplicadas a conservacion-restauracion del patrimonio metalico*, Madrid 2011. (online)

33. Barrio Martin, J.; Chamon Frenandez, J. Proyecto Dorados: tecnología, conservación y restauración de los metales dorados medievales, Madrid 2011.
34. La técnica radiográfica en los metales históricos (English translation included), Madrid 2011. (online)
35. Konzervování a restaurování kovů. Ochrana předmětů kulturního dědictví z kovů a jejich slitin, Brno 2011.
36. Knaut, M.; Jeberien, A. (Hrsg.): Adel verpflichtet - Forschungen und Ergebnisse zur Konservierung und Restaurierung der barockzeitlichen Särge vom Schlossplatz Berlin-Mitte, Berlin 2012.
37. Conservation of Metal Objects, National Research Institute of Cultural Heritage, Daejeon (S.Korea) 2012.
38. Schmutzler, B. Rettung vor dem Rost, Rahden 2012.
39. Landesamt f. Denkmalpfl. u. Archäologie Sachsen-Anhalt (Hrsg.): Die Merseburger Fürstengruft Geschichte, Zeremoniell, Restaurierung, Halle 2013.
40. Kuhn, H.; Emerling, E. Werke aus Kupfer, Bronze und Messing, Muenchen 2014.
8. Scott, A. The cleaning and restoration of museum exhibits, 3d report. British Museum, Department of Scientific and Industrial Research. London 1926. (Russian edition online)
9. Nichols, H. W. Restoration of ancient bronzes and cure of malignant patina. Chicago 1930. (online)
10. Lucas, A. Antiques: Their restoration and preservation. London 1932. (online)
11. Plenderleith, H.J. The preservation of Antiquities, London 1934 (Chapter on metals conservation)
12. Ocherki po metodike tehnologicheskog issledovaniya restavratsii i konservatsii drevnih metalicheskikh izdeliy, Moscow 1935. (online)
13. Farmakovskiy, M.V. Konservatsiya i restavratsiya muzeinikh kollektsiy, Moscow 1946 (chapter on metals conservation) (online)
14. Plenderleith, H.J. The Conservation of Antiquities and Works of Art, London 1956 (chapter on metals conservation)
15. France-Lanord, A. La conservation des antiquités métalliques, Paris 1962.

### 13.3 Important older books

1. Rathgen, F. Die Konservierung von Altertumsfunden, Berlin 1898 (chapter on metals conservation). (English edition online)
2. Flinders Petrie, W.M. The Method and Aims in Archaeology, London 1904 (chapter on conservation) (online)
3. Rosenberg, G. Antiquités en fer et en bronze : leur transformation dans la terre contenant de l'acide carbonique et des chlorures et leur conservation, Copenhagen 1917.
4. Scott, A. The cleaning and restoration of museum exhibits (report upon investigation conducted at the British Museum, Department of Scientific and Industrial Research). London 1921.
5. Scott, A. The cleaning and restoration of museum exhibits, 2d report. British Museum, Department of Scientific and Industrial Research. London 1923.
6. Fink, C.G.; Eldridge, C.H. The restoration of ancient bronzes and other alloys, New York 1925.
7. Galnbek, I.A. Ochistka i sokhranenie metalicheskikh predmetov drevnosti, Leningrad 1925 (first book dedicated to metals conservation/not only bronze and iron)

## 14 Online magazines

- BROMECA Bulletin of Research on Metal Conservation

## 15 Metals conservation blogs

1. Armas protohistóricas con magnetita, by Jesús Alonso López
2. Conservation of metals - by Catia Viegas-Wesolowska
3. Staffordshire Hoard Blog

## 16 Free software that can be used for metals conservation

1. The Use of Expert Systems in Conservation
2. The Modular Cleaning Program
3. Download free conservators documentation software
4. Freecorp-simple corrosion prediction software
5. Online Cellular Automata based corrosion simulation

## 17 See also

- Conservation and restoration of outdoor bronze artworks
- Conservation and restoration of copper-based objects
- Conservation and restoration of ferrous objects
- Conservation and restoration of glass objects
- Conservation and restoration of ivory objects
- Conservation and restoration of ceramic objects
- Conservation and restoration of silver objects

## 18 References

- [1] Moorey, P. R. S., (1988). Early Metallurgy in Mesopotamia, in *The Beginning of the Use of Metals and Alloys. Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys*, Zhengzhou, China, 21–26 October 1986., ed. R. Maddin Cambridge, Massachusetts & London, England: The MIT Press.
- [2] [http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs\\_PreservationOfMetallicCulturalHeritage.pdf](http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs_PreservationOfMetallicCulturalHeritage.pdf) Accessed 16.01.2012.
- [3] [http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs\\_PreservationOfMetallicCulturalHeritage.pdf](http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs_PreservationOfMetallicCulturalHeritage.pdf) Accessed 16.01.2012.
- [4] Thompson, J.C.: On restoring sacred objects <http://cool.conservation-us.org/byauth/thompson/sacred/>
- [5] Nikitin, M.K.; Melynikova, E.P. Himiya v restavracii, Leningrad 1990., p.176
- [6] Nikitin, M.K.; Melynikova, E.P. Himiya v restavracii, Leningrad 1990., p.176
- [7] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [8] Nikitin, M.K.; Melynikova, E.P. Himiya v restavracii, Leningrad 1990., p.176
- [9] USPT 4,640,713
- [10] H. Brinch-Madsen, “Die reinigung von eisen mit ammoniakalischer Citronensaure”, *Arbeitsblätter für Restauratoren* 2/1974
- [11] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [12] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [13] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [14] H. Brinch-Madsen, “Die reinigung von eisen mit ammoniakalischer Citronensaure”, *Arbeitsblätter für Restauratoren* 2/1974
- [15] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [16] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [17] Baboian, R. (Ed.) *Corrosion Tests and Standards*, Baltimore 2005.
- [18] P. Mottner: *Der Aktuell Wissensstand zur Korrosion und Restaurierung/Konservierung von Denkmälern aus Blei, Zinn, Zink (eine dokumentation)*, Munich 1993.
- [19] Stambolov, T.; Eichelmann, N.; Bleck, R.D. Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I Weimar 1987.
- [20] P. Mottner: *Der Aktuell Wissensstand zur Korrosion und Restaurierung/Konservierung von Denkmälern aus Blei, Zinn, Zink (eine dokumentation)*, Munich 1993.
- [21] P. Mottner: *Der Aktuell Wissensstand zur Korrosion und Restaurierung/Konservierung von Denkmälern aus Blei, Zinn, Zink (eine dokumentation)*, Munich 1993.
- [22] Baboian, R. (Ed.) *Corrosion Tests and Standards*, Baltimore 2005.
- [23] A. Timar-Balazsy, D. Eastop, *Chemical principles of textile conservation*, Butterworth Heinemann, 1998.
- [24] “Surface treatment of titanium,” *The Titanium Information Group*, Rotherham 1998.
- [25] Kunze, E. *Korrosion und Korrosionsschutz*, Berlin 2001.
- [26] USPT 4,264,418
- [27] USPT 4,264,418
- [28] <http://www.uva.nl/en/about-the-uva/organisation/faculties/content/faculteit-der-geesteswetenschappen/shared-content/events/workshops/2013/10/masterclass-3d.html> Retrieved 13.12.2013.
- [29] [http://www.alsacorp.com/products/mirrachrome/mirra\\_proinfo.htm](http://www.alsacorp.com/products/mirrachrome/mirra_proinfo.htm)
- [30] <http://www.bare-metal.com/bare-metal-foil.html>
- [31] [http://www.alsacorp.com/products/mirrachrome/mirra\\_proinfo.htm](http://www.alsacorp.com/products/mirrachrome/mirra_proinfo.htm)
- [32] <http://www.bare-metal.com/bare-metal-foil.html>
- [33] Brinch Madsen, H. A preliminary note on the use of benzotriazole for stabilizing bronze objects, *Studies in Conservation* 12/4 1967.

- [34] [http://www.medal-project.eu/11-Copper\\_conservation.swf](http://www.medal-project.eu/11-Copper_conservation.swf), Accessed 19.01.2012.
- [35] Cardoso, M.O. Study of a 9th century Silver Earrings Set from Mikulčice: Corrosion, Conservation and Maintenance; Lisboa 2010. MA thesis
- [36] MOUREY W., La Conservation des Antiquities Metalliques – de la Fouille au Musee, L.C.R.R.A., Draguignan, 1981, p. 133
- [37] <http://nautarch.tamu.edu/CRL/conservationmanual/File12.htm#Sodium>
- [38] Brinch Madsen, H. A preliminary note on the use of benzotriazole for stabilizing bronze objects, *Studies in Conservation* 12/4 1967.
- [39] [http://www.medal-project.eu/11-Copper\\_conservation.swf](http://www.medal-project.eu/11-Copper_conservation.swf), Accessed 19.01.2012.
- [40] Белкин А.П., Нацкий М.В. Метод-обработки очагов "бронзовой болезни" медных сплавов сульфидами аммония // Реставрация памятников истории и культуры / ГБЛ, Информкультура / Экспресс-информация. - М., 1987. Вып. 3. - С. 6-8.
- [41] <http://art-con.ru/node/1761>, accessed 19.01.2012.
- [42] Affaizza Mohd Shah, Afidah Abdul Rahim, Shafida Abdul Hamid, Solhan Yahya, "Mangrove (*Rhizophora apiculata*) tannins as green corrosion inhibitors for copper in acidic medium", *Refereed Proceedings of ICORAFSS 2009*, 2–4 June 2009, Johor Bahru, Malaysia, 146-149. [ISBN 978-983-9805-73-4]
- [43] Gilberg, M.; Seeley, N. The Alkaline Sodium Sulphite Reduction Process for Archaeological Iron: A Closer Look, *Studies in Conservation*, London 1982.
- [44] [http://www.viks.sk/chk/studcon\\_2\\_05\\_81\\_100.doc](http://www.viks.sk/chk/studcon_2_05_81_100.doc) Selwyn, L.; Argyropoulos, V. Removal of Chloride and Iron Ions from Archaeological Wrought Iron with Sodium Hydroxide and Ethylenediamine Solutions Accessed 12.04.2012.
- [45] T. Stambolov, R.D. Bleck, N. Eichelmann, *Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I*, Weimar, 1987.
- [46] T. Stambolov, R.D. Bleck, N. Eichelmann, *Korrosion und Konservierung von Kunst und Kulturgut aus Metall/I*, Weimar, 1987.
- [47] <https://biblio.ugent.be/input/record?func=publicRecord&recordOID=000470013&context=search>, Accessed 19.01.2012.
- [48] <http://www.heritagesciencejournal.com/content/2/1/14/abstract> Accessed 27.08.2014.
- [49] Brinch Madsen, H. A preliminary note on the use of benzotriazole for stabilizing bronze objects, *Studies in Conservation* 12/4 1967.
- [50] USPT 6,805,756
- [51] MacLeod, I.D. Stabilization of corroded aluminum: the Bertram Seaplane Float <http://www.museum.wa.gov.au/maritime-archaeology-websites/default/files/mcleod.doc> Accessed 12.03.2012
- [52] USPT 4,054,466
- [53] S. Yahya, A. Abdul Rahim, R. Adnan, A. Mohd Shah, R. Adnan, "Tannins: Eco-friendly corrosion inhibitors for aluminium alloy", *Refereed Proceedings of the Symposium of USM Fellowship Holders 2009*, 14–15 November 2009, USM, Penang [ISBN 978-967-5417-48-1]
- [54] *Aluminium-Taschenbuch*, Duesseldorf 1963.
- [55] [http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs\\_PreservationOfMetallicCulturalHeritage.pdf](http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs_PreservationOfMetallicCulturalHeritage.pdf) Accessed 16.01.2012.
- [56] Phenix, A. 1992. Solvents for Paraloid B-72. *Conservation News* 48:21–3.
- [57] Feller, R.L., N. Stolow, and E.H. Jones. 1985. On picture varnishes and their solvents. Revised and enlarged ed. Washington, D.C.: National Gallery of Art
- [58] C.V. Horie *Materials for Conservation*, Oxford 2010.
- [59] C.V. Horie *Materials for Conservation*, Oxford 2010.
- [60] Scott, D.A. *Copper and Bronze in Art: Corrosion, Colorants, Conservation*, Los Angeles 2002.
- [61] Selwitz, C *Cellulose Nitrate in Conservation*
- [62] Mottner, P; Pilz, M. Ormocer(R)e - Eine Neue Verbindungsklasse zur Konservierung von Bronzeoberflächen an Denkmälern, in book *Bronze und Galvanoplastik -Geschichte - Materialanalyse - Restaurierung*, Dresden 2001.
- [63] <http://www.pantarol.de/index.php/shopsystem/pantarol-a-Pristup-stranici> 28.08.2014.
- [64] <http://www.everbritecoatings.com/ProtectaClear.htm> Accessed 28.08.2014.
- [65] <http://www.everbritecoatings.com/cart/everbrite-coating-only-c-6.html> Accessed 28.08.2014.
- [66] [http://www.picreator.co.uk/articles/3\\_renaissance\\_wax.htm](http://www.picreator.co.uk/articles/3_renaissance_wax.htm)
- [67] Otien Alego, V.; Heath, G.; Hallam, D.; Creagh, D. Electrochemical evaluation of the anti-corrosion performance of waxy coatings for outdoor bronze conservation, *METAL 98: proceedings of the international conference on metals conservation*, Draughtman 1998.
- [68] [http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs\\_PreservationOfMetallicCulturalHeritage.pdf](http://www.elsevierdirect.com/brochures/shreir/PDF/Shreirs_PreservationOfMetallicCulturalHeritage.pdf) Accessed 11.07.2012.
- [69] Nikitin, MK; Melnikova, EP *Himija v restavracii*, Leningrad 1990th str.268
- [70] Huck, J; Bleck, RD *Chemikalien und Rezepte*, Weimar 1990th

- [71] <http://www.ingolstadt.de/stadtmuseum/scheuerer/ausstell/bernst04.htm> archaeological site access 23.03.2012.
- [72] Ham, CH, Shin, B. Amber Artifact Consolidation Case Study: Impact of Organic Solvents on Amber Artifacts, Abstracts from the 37th Annual Conference of the Canadian Association for Conservation of Cultural Property, Winnipeg 2011th
- [73] <http://www.cr.nps.gov/museum/publications/conservoogram/11-17.pdf> Access to the site Aus Bruchstücken rekonstruiert Ein Bernsteinkästchen der Gothaer Kunstkammer
- [74] [http://www.getty.edu/conservation/publications\\_resources/pdf\\_publications/urushi.html](http://www.getty.edu/conservation/publications_resources/pdf_publications/urushi.html) Accessed 10/02/2012
- [75] [http://cool.conservation-us.org/jaic/articles/jaic37-01-009\\_idx.html](http://cool.conservation-us.org/jaic/articles/jaic37-01-009_idx.html) Accessed 2.10.2012.
- [76] <http://art-con.ru/node/651>. Accessed 04.12.2012.
- [77] [http://cool.conservation-us.org/jaic/articles/jaic37-01-009\\_2.html](http://cool.conservation-us.org/jaic/articles/jaic37-01-009_2.html) Accessed 18.11.2012 page.
- [78] Nikitin, M.K.; Melynikova, E.P. Himiya v restavracii, Leningrad 1990., p.272.
- [79] Nikitin, M.K.; Melynikova, E.P.. Himiya v restavracii, Leningrad 1990., p.271
- [80] [http://www.mnhs.org/preserve/conservation/reports/shell\\_objects.pdf](http://www.mnhs.org/preserve/conservation/reports/shell_objects.pdf) Accessed 17.10.2012.
- [81] <http://art-con.ru/node/4473> Accessed 29.11.2012.
- [82] Nikitin, M.K.; Melynikova, E.P. Himiya v restavracii, Leningrad 1990., p.269
- [83] <http://www.vam.ac.uk/content/articles/c/caring-for-plaster/> Retrieved at 3.10.2013.
- [84] <http://www.uva.nl/en/about-the-uva/organisation/faculties/content/faculteit-der-geesteswetenschappen/shared-content/events/workshops/2013/10/masterclass-3d.html> Retrieved 13.12.2013.
- [85] Budija Goran: Čišćenje, zaštita i održavanje umjetničkih predmeta i starina od metala, version december 2010., Zagreb, [http://www.e-insitu.com/images/fbfiles/files/BUDIJA\\_Ciscenje2.pdf](http://www.e-insitu.com/images/fbfiles/files/BUDIJA_Ciscenje2.pdf)
4. Коррозионные разрушения археологического железа и методы его стабилизации
5. MEDAL project
6. UCLA metals course-archived presentations
7. Society for Historical Archaeology-Conservation FAQ and facts
8. Building Conservation-articles on metals conservation
9. Development and Testing of Organic Coatings for the Protection of Outdoor Bronze Sculpture from Air-Pollutant Enhanced Corrosion — Year (2001-09)
10. Development and Testing of Organic Coatings for the Protection of Outdoor Bronze Sculpture from Air-Pollutant Enhanced Corrosion — Year 2 (2001-08)
11. Development and Testing of Organic Coatings for the Preservation of Outdoor Bronze Sculpture from Air-Pollutant Enhanced Corrosion – Year 3 (2002-18)
12. Development and Evaluation of Removable Protective Coatings on Bronze (2004-27)
13. Research Into Protective Coating Systems for Outdoor Bronze Sculpture and Ornamentation Phase I (1997-03)
14. Research into Protective Coating Systems for Outdoor Bronze Sculpture and Ornamentation Phase II (1999-23)
15. Research into Protective Coating Systems for Outdoor Bronze Sculpture and Ornamentation Phase III (2000-08)
16. R.W. Hoge: Conservation Rules for Coins and Medals
17. A Framework for Conservation of metals
18. Recognizing Metals and their Corrosion Products
19. Schotte, B. Adriaens, A. Treatments of Corroded Lead Artefacts - An Overview
20. A Simple Guide for Archaeological Materials Characterization
21. Russian article on tannin based treatment of “bronze disease” (in Russian - Try Google Translator, it is free)
22. Metallography and Microstructure of Ancient and Historic Metals-download free book
23. Ancient and Historic Metals-Conservation and Scientific Research-download free book

## 19 External links

1. ICOM CC WG Metals
2. BROMEC - Bulletin of Research On Metal Conservation
3. METALConsinfo (Metals Conservation Catalog subpage - including big collection of links //300 links!!!/)



24. METAL 2004-proceedings of conference
25. Big Stuff 2004. - conference papers
26. Big Stuff 2007. - conference papers
27. CONSIST project
28. Hamilton, D. Methods of Conserving Archaeological Material from Underwater Sites
29. РЕСТАВРАЦИЯ МЕТАЛЛА. Методические рекомендации (1989)(in Russian – try Google translator – it is free, translation can be very silly)
30. Native American Jewelry Conservation Project: Part 2
31. Koh, Y.S. Laser Cleaning as a Conservation Technique for Corroded Metal Artifacts, doctoral thesis, Lulea 2006.
32. Siano, S. Laser Ablation in Conservation of Artworks
33. CCI Notes 9/2 Storage of Metals
34. CCI Notes 9/1 Recognizing Active Corrosion
35. CCI Notes 9/4 Basic Care of Coins and Medals
36. Watkinson, D. Preservation of Metallic Cultural Heritage, 2010.
37. Boissonnas, V. An introduction to the history of metals conservation
38. Preservapedia - Metals conservation
39. Grissom, C.A. The Conservation of American War Memorials Made of Zinc
40. Bailey, G.T. Stabilization of wrecked and corroded aluminium aircraft
41. CCI Notes 9/3 The Cleaning, Polishing and Protective Waxing of Brass and Copper
42. CCI Silver Care and Tarnish removal
43. CCI Notes 9/8 Mechanical Removal of Rust from Machined Ferrous Surfaces
44. CCI Notes 9/5 Tannic Acid Treatment
45. Care and Conservation of Pewter
46. Conservation of lead sculpture
47. Conservation of lead, tin and lead alloys
48. Diaz Martinez, S.; Garcia Alonso, E. Técnicas metodológicas aplicadas a la conservación-restauración del patrimonio metálico, Madrid 2011.
49. Watkinson, D. Conserving cultural material : Ethical challenges for the conservator
50. Mach, M.; Doktor, A.; Meissner, B. Bronze und Galvanoplastik-Geschichte-Materialanalyse-Restauration, Dresden 2001.
51. Minimum Common Standards Definition – Model Curricula Metals -EQF Level 7 - ECPL
52. Laboratoire d'archéologie des métaux, Nancy
53. The TIGHAR Guide to Aviation Historic Preservation Terminology
54. Hayha, H. THE HISTORY OF IRON PROTECTION. DESCRIPTION OF MATERIALS AND EVALUATION OF THEIR PROPERTIES
55. La técnica radiográfica en los metales históricos (English translation included), Madrid 2011.
56. National Research Laboratory for Conservation of Cultural Property, Lucknow, India-research papers, some good articles on metals conservation
57. Regis Bertholon: La limite de la surface d'origine des objets métalliques archéologiques - doctoral thesis
58. Castillo Narrea, L.E.J.A. Conservación y Restauración de algunos objetos arqueológicos: Arte, Técnica y Metalurgia, Santiago de Chile 2008. - thesis
59. L.B. Brostoff: Coating Strategies for the Protection of Outdoor Bronze Art and Ornamentation (thesis)
60. Care and Handling of Bronze Objects
61. Wanhill, R.J.H. Brittle archaeological silver- identification, restoration and conservation
62. Strandberg, H. Perspectives on Bronze Sculpture Conservation. Modelling Copper and Bronze Corrosion, thesis
63. Conservation of iron and steelwork in historic structures and machinery/Maintenance handbook
64. Finishing Techniques in Metalwork
65. Marušić, K. Protection of patinated bronze by non toxic inhibitors, thesis, Zagreb 2010.
66. AIC Metals Conservation wiki
67. Care of Objects Made of Zinc
68. Aircraft Restoration Practice and Philosophy
69. Anais 2. Congresso Latino-americano de restauração de metais, Rio de Janeiro 2005.
70. The France-Lanord collection
71. Archaeological Iron Conservation Colloquium 2010 Abstracts/1

72. Archaeological Iron Conservation Colloquium 2010 Abstracts /2
  73. Archaeological Iron Conservation Colloquium 2010 Abstracts /3
  74. Archaeological Iron Conservation Colloquium 2010 Abstracts/4
  75. Archaeological Iron Conservation Colloquium 2010 Abstracts/posters
  76. Bronze colloquium 2012. conference brochure
  77. Ligas metálicas : Investigação e conservação (2008.)
  78. Preservacao de artefatos ornamentais de ferro integrados a arquitetura...
  79. Funcionalidad vs conservacion en piezas de orfebreria...
  80. METAL 2010. proceedings
  81. Creating a microclimate box for metal storage
  82. Identifying Archaeological Metal
  83. IV Congreso Latinoamericano de Conservación y Restauración de Metal
  84. Conservation Case Studies: A medieval tabernacle from Cologne
  85. Cleaning treatment of a tarnished Daguerreotype by using the reducing afterglow of an atmospheric plasma
  86. Plazmochemické procesy a technologie pro konzervaci kovových archeologických předmětů
  87. Protection of metal artifacts with the formation of metal-oxalates complexes by Beauveria bassiana
  88. The Croatian Apoxyomenos
  89. La practca de la limpieza con laser en materiales metalicos - hierro, cobre, plata
  90. Серебряный кратир из Новгорода отреставрируют лазером
  91. Mass conservation of archaeological iron artifacta
  92. Metals in America's Historic Buildings - Uses and Preservation Treatments
  93. Guidelines for the Storage and Display of Archaeological Metalwork
  94. NHIG Conservation Principles for Heritage Forged and Cast Ironwork
- ## 20 Metals conservation video files
1. Conserving Bronze: The Lamp with Eros from Vani
  2. Caring for Metals - Housekeeping for Historic Sites
  3. USS Monitor Engine Removed from Water
  4. Laser Cleaning of Bronze Eagle in Oak Park
  5. Re-Constructing Silver Objects from the Staffordshire Hoard
  6. Erik Risser Describes the Conservation of the Apollo Saettante at the Getty Villa
  7. CoinScubber - Cleaning Ancient Coins
  8. Cleaning an Outdoor Sculpture Part I
  9. Parlament Wien, Quadriga, Restaurierung, Bronze
  10. Dorure au mercure
  11. Repatination of a Bronze WWII Memorial Plaque
  12. how to care for bronze sculptures
  13. Restoring an Artifact at the SCCRRMM
  14. Clemson Conservation Center: H.L. Hunley submarine - Part 1/3
  15. NCPTT Iron Fence Repair - Cemetery Monument Conservation
  16. Restoration of the USS Monitor
  17. Apoxyomenos de Croacia 5
  18. Bronze Age Fibula
  19. Masterclass -silverplating
  20. Patina & corrosion surfaces on ancient bronzes
  21. Campanas medievales limpieza criogenica
  22. Restauro David Donatello
  23. Cruz Parroquial de la iglesia de Santa María de la Asunción de Estepa (Sevilla)
  24. Il nuovo intervento di restauro sui Bronzi di Riace
  25. Il restauro della base originale del Cinghiale in Firenze
  26. Restauración y conservación de los cañones de La Sabana
  27. Conservation of iron artefacts at Jamestown
  28. Cleaning the Staffordshire Hoard - K551 and K1775

## 21 Text and image sources, contributors, and licenses

### 21.1 Text

- **Conservation and restoration of metals** *Source:* <http://en.wikipedia.org/wiki/Conservation%20and%20restoration%20of%20metals?oldid=646637769> *Contributors:* William Avery, Icairns, Tabletop, BD2412, Kolbasz, Bgwhite, Edgar181, Gilliam, Chris the speller, Paul venter, Cydebot, Magioladitis, Rivertorch, RichardMcCoy, Squids and Chips, Billinghamurst, Lamro, Bentogoa, Arjayay, SchreiberBike, ChrisHodgesUK, Heironymous Rowe, XLinkBot, Good Olfactory, Addbot, Ronschmidting, Yobot, Rose Daly, Bility, LilHelpa, Mathonius, Eugene-elgato, FrescoBot, John of Reading, Dewritech, ZéroBot, Rocketrod1960, Whoop whoop pull up, ClueBot NG, Gb777, DPL bot, Tovalu, Morning Sunshine, YFdyh-bot, AngelKelley, Mogism, Lliberopoulou, Argarico, Esteb83 and Anonymous: 247

### 21.2 Images

- **File:Cratère\_de\_Derveni\_0001.jpg** *Source:* [http://upload.wikimedia.org/wikipedia/commons/9/95/Crat%C3%A8re\\_de\\_Derveni\\_0001.jpg](http://upload.wikimedia.org/wikipedia/commons/9/95/Crat%C3%A8re_de_Derveni_0001.jpg) *License:* CC BY-SA 2.5 *Contributors:* ? *Original artist:* ?
- **File:HorsesSaintMark1.jpg** *Source:* <http://upload.wikimedia.org/wikipedia/commons/d/d8/HorsesSaintMark1.jpg> *License:* CC BY-SA 3.0 *Contributors:* Own work *Original artist:* Etan J. Tal
- **File:PerseusSignoriaStatue.jpg** *Source:* <http://upload.wikimedia.org/wikipedia/commons/5/52/PerseusSignoriaStatue.jpg> *License:* Public domain *Contributors:* Originally from en.wikipedia; description page is/was here. *Original artist:* Original uploader was Jrouso at en.wikipedia
- **File:Zagreb\_Apoxomenos\_-\_figure.JPG** *Source:* [http://upload.wikimedia.org/wikipedia/commons/f/f7/Zagreb\\_Apoxomenos\\_-\\_figure.JPG](http://upload.wikimedia.org/wikipedia/commons/f/f7/Zagreb_Apoxomenos_-_figure.JPG) *License:* Public domain *Contributors:* Own work *Original artist:* User:Zmaj

### 21.3 Content license

- Creative Commons Attribution-Share Alike 3.0