ECSS-Q-ST-70-03C
31 July 2008

EUROPEAN COOPERATION
FOR SPACE STANDARDIZATION

Space product assurance

Black-anodizing of metals with inorganic dyes

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS Executive Secretariat, endorsed by the Document and Discipline Focal Points, and approved by the ECSS Technical Authority.

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Published by: ESA Requirements and Standards Division
ESTEC, P.O. Box 299,
2200 AG Noordwijk
The Netherlands

Change log

ECSS-Q-70-03A 7 April 2006	First issue Transforming ESA-PSS-01-703 into an ECSS Standard
ECSS-Q-70-03B	Never issued
ECSS-Q-ST-70-03C 31 July 2008	Second issue Redrafting of ECSS-Q-70-03A according to new ECSS drafting rules and template. In particular: • Clauses 5, 6 and 7 combined into one Clause 5 "Requirements". • Requirements included in Clause 4 moved into Clause 5. • General cleaning of text to comply with ECSS formatting rules.

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Introduction

Passive thermal control systems onboard spacecraft are often based on the thermo-optical properties of the surfaces, namely emissivity and absorbance. The ratio of these two properties defines the equilibrium temperature of the surface. This Standard provides requirements for black-anodizing surface treatment applied on metallic surfaces to achieve an emissivity versus absorbance ratio close to unity, as requested for many applications.

1
Scope

This Standard defines requirements for measurements and verifications to guarantee that an anodized coating is adequate for the intended application. The requirements set by this Standard ensure high reliability of surface treatments intended to withstand normal terrestrial conditions and environment loads imposed on spacecraft and associated equipment where surfaces require high solar absorptance, high emittance, high optical blackness, or a combination of these properties.

This standard may be tailored for the specific characteristics and constraints of a space project, in conformance with ECSS-S-ST-00.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply, However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system – Glossary of terms
ECSS-Q-ST-20	Space product assurance – Quality assurance
ECSS-Q-ST-70	Space product assurance – Materials, mechanical parts and processes
ECSS-Q-ST-70-04	Space product assurance – Thermal testing for the evaluation of space materials, processes, mechanical parts and assemblies
ECSS-Q-ST-70-09	Space product assurance – Measurement of thermo-optical properties of thermal control materials
ECSS-Q-ST-70-13	Space product assurance – Measurements of the peel and pull-off strength of coatings and finishes using pressure-sensitive tapes

3 Terms, definitions and abbreviated terms

3.1 Terms defined in other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 anodizing

placing a film coating on a metal surface by an electrolytic or chemical action

3.2.2 batch (material)

material that originates from the same casting lot, and followed the same transformation processes and the same heat treatment

3.2.3 emittance (ε)

ratio of the radiant intensity of the specimen to that emitted by a black body radiator at the same temperature and under the same geometric and wavelength conditions

NOTE Differentiation is made between:

- Hemispherical emittance (ε_h) - conditions for incidence or viewing of flux over a hemispherical region.
- Normal emittance (ε_n) - conditions for incidence or viewing through a solid angle normal to the specimen. Ratio refers to the emissivity normal to the surface of the emitting body.

3.2.4 solar absorbance (α_s)

ratio of the solar radiant flux absorbed by a material (or body) to that incident upon it

NOTE Measurement methods are:

- Spectroscopic method using a photo-spectrometer covering the range from 0,25 µm up to 2,5 μm for the determination of α_s.

- Portable equipment using a xenon flash for relative measurements (α_p)

3.2.5 test piece

piece that follows a treatment as close as possible than that is applied on the workpieces with the purpose of assessing the suitability of the process

NOTE A test piece can be destructively tested.

3.2.6 workpiece

piece that is intended to be used as space-hardware and for which the adequacy of the treatment is assessed by tests performed on work pieces treated in as similar as possible conditions than the workpiece

4 Principles

The black-anodizing of a metal consists of submitting the part to be coated to a controlled oxidation treatment during which the metallic surface is transformed into an oxide layer, partly growing in the substrate. Compounds or dyes are sealed in the oxidized layer, thus providing the required optical or thermo-optical properties to the surface.

For space applications, only inorganic dyes are suitable, as radiation do not strongly impact on their thermo-optical properties.

Depending on the specific project requirements, the coating fulfils part or all the acceptance criteria given in this Standard.

Not all metals and alloys are suitable for black- anodizing treatment. The most commonly treated are titanium, aluminium and their alloys. In particular, the composition of the alloy, the manufacturing process and the alloy temper can have an impact on the response to the black- anodizing.

Aluminium alloys containing a high amount of copper (5 %), zinc (6 %) or silicon (5 %) are known to respond poorly to some treatments.

Wrought alloys are generally easier to treat than cast alloys.

The manufacturing process of the part to be coated can have an impact on its response to the black- anodizing process. Also the geometry of the hardware can limit the possibility to coat the part. The surface quality of the parts to be coated has an influence of the coating results, since the anodization layer mimics the surface characteristics of the underlying substrate.

Several requirements are therefore identified in order to select and prepare suitable work-pieces.

Annex A describes for information a coating process for aluminium alloy.

5 Requirements

5.1 Prior to anodizing

a. The supplier shall ensure that no damages or degradations occurred during handling and transportation of the parts to be black anodized.

NOTE The coating mimics all imperfections of the surface.

b. In case of scratching, shock or any other event disturbing the surface aspect, the customer shall be informed and a nonconformance report issued.

c. The growth mechanisms of the layer and its impact on final hardware dimensions, including the potential grinding off of a porous part, shall be communicated to the customer.

NOTE The layer formed during anodizing consumes the bulk metal to grow both within and outside the initial dimensions of the bulk.

d. The customer shall provide a written agreement on geometry impact prior to starting the black-anodizing process.

5.2 Work-piece selection and preparation

a. The parts to be treated shall be made of the same alloy and shall be from the same batch.

b. The parts shall only be made of the metal to be black-anodized, and any insertion of another metal shall be avoided.

c. The parts shall be designed in such a way that the chemical products used in the process can be thoroughly rinsed.

NOTE The presence of drain holes is a possible means to avoid the retention of chemical within the hardware.

d. The parts shall contain no screws, no rivets nor other fastener elements.

e. If a part contains welded elements, a verification programme shall be set up to qualify the black anodizing on the specific weld which includes a verification of the cleaning method used to rinse off the chemicals used for anodizing.

f. If a brazing alloy is used, the compatibility of the brazing material with the black-anodizing process shall be demonstrated.

g. Only welding and brazing processes for which the seam is continuous shall be used.

h. A surface preparation treatment shall be performed on the part to be coated to remove any oil dust or other contaminants from the surface.

i. Lint-free gloves or surgical latex talc-free gloves shall be worn during selection and preparation of the parts.

NOTE 1 Other surface treatments can be applied to the part to improve the quality of the surface or increase its roughness.

NOTE 2 Masking can be applied to the parts not to be anodized.

5.3 Facilities

a. The work area shall be clean and free of dust.

b. Air used for ventilation shall be filtered to prevent contamination of the work-pieces by moisture, oil or dust.

c. The environmental conditions shall meet requirements of national health regulations.

d. Equipment for protection of persons in the work area shall be according to national health regulations.

5.4 Anodizing

5.4.1 General

a. The adequacy of the coating process shall be demonstrated through a verification programme in conformance with ECSS-Q-ST-70 Table 4.1.

5.4.2 Process control

a. An electrical contact shall be employed for each part to be anodized.

b. The electrical contact shall be of a size compatible with the size of the hardware to be processed and compatible with the black anodizing process specifications.

c. The location of the electrical contact shall not interfere with the functional usage of the part to be treated.

d. The following process parameter shall be controlled:

1. applied electrical current characteristics (voltage, intensity, current density),
2. composition and pH-value of the electrolyte,

3. location of the electrodes and their distance with respect to the part,
4. temperature of the bath,
5. stirring parameter of the bath,
6. volume of the electrolyte with respect to that of the treated part,
7. process time.

e. A record of the process data shall be part of the process procedure.

5.4.3 Two-step and integral colouring methods

5.4.3.1 Two-step colouring

a. The process shall be carried out in the following two steps:

1. Step 1: The part is immersed in a bath containing an inorganic dye (metal compound).

   NOTE 1 Commonly used metals include tin, cobalt, nickel, and copper.

   NOTE 2 The dye particles are driven into the pores of the oxide, with or without a current applied.

2. Step 2: The pores are then sealed.

   NOTE 1 Sealing can be done by immersion of the part in a boiling water based solution.

   NOTE 2 After anodizing, the obtained oxide layer presents a columnar porous structure.

b. After completion of the process it shall be verified that:

1. the specified thermo-optical properties are obtained with the minimum amount of dye in the coating in conformance with ECSS-Q-ST-70-09;
2. the coating does not expel dye during adhesion in conformance with ECSS-Q-ST-70-13.

   NOTE 1 This ensures that the pores of the coating are sealed.

   NOTE 2 A typical coating thickness for the two-step colouring is 20 μm.

5.4.3.2 Integral colouring (one step process)

a. In integral colouring process, anodizing and colouring shall be combined to simultaneously form and colour the oxide cell wall.

   NOTE The layer obtained is generally very dense close to the bulk and porous in its outer part.

b. After completion of the process, it shall be verified that:

1. the porous part of the coating is treated according to the process specifications;

   NOTE The porous part is ground-off in most cases;

2. the required thermo-optical properties are obtained in conformance with ECSS-Q-ST-70-09.

NOTE A typical coating thickness is 8 µm.

5.4.4 Treatment termination

a. After completion of the black- anodizing process, the treated part shall be thoroughly rinsed in water and distilled water and then dried.

5.5 Handling and storage of materials and parts

5.5.1 Material storage

a. The materials shall be stored in a cleanliness-controlled area, with an ambient temperature of (20 ± 3) °C and a relative humidity of (55 ± 10) %.

b. The parts shall be stored in such a way as to prevent any damage or contamination by dust, moisture or grease.

c. Limited-life materials shall be labelled with their shelf lives and date of manufacture, or alternatively the date of delivery.

5.5.2 Material handling and storage

a. Lint-free gloves or surgical latex talc-free gloves shall be worn during selection and preparation of the parts.

b. Coated parts shall only be handled with clean nylon or lint-free gloves.

c. The coated parts shall not be bent, twisted or subjected to any stress that can damage the coating.

d. Coated surfaces shall be shielded from contact by using polyethylene or polypropylene bags or sheets.

e. Mechanical damage shall be avoided by packing the polyethylene- or polypropylene-wrapped work-pieces in clean, dust- and lint-free material.

5.6 Acceptance criteria

5.6.1 General

a. Black- anodizing of a piece of hardware shall be performed in one single run.

5.6.2 Visual inspection

a. The parts shall be visually inspected with the naked eye, in particular at the locations of joints and small gaps.

b. Changes in surface colour or aspect shall be reported as input for the acceptance testing.

5.6.3 Verification testing

5.6.3.1 Test piece definition

a. Every batch shall be subjected to acceptance tests.

b. The suitability of the alloy with respect to the anodizing process shall be demonstrated on test pieces having the same specific characteristics as the work-piece.

c. Test pieces shall

1. be from the same material batch as the work-pieces;
2. have followed the same manufacturing process (including surface finishing);
3. be cut in the same direction;
4. have the same geometries and welding features as the work-pieces;
5. have the specific characteristics of the work-pieces;

   NOTE For example: brazed joint and small gap.

6. be prepared at the same time as the work-pieces to enable destructive and other tests.

5.6.3.2 Acceptance test

a. Thermo-optical properties of the parts shall be measured according to ECSS-Q-ST-70-09 to verify the following requirements:

1. Solar absorptance (α_s) at least 0,93, and
2. Normal emittance (ε_n) at least 0,90.

   NOTE The colour uniformity assessed by visual inspection is not directly linked to the above measurements, as the wavelengths of interest are not the same. The absorbtance and emittance uniformity is therefore often verified using the visual colour uniformity as input.

b. Thermal cycling. test shall be performed in conformance with ECSS-Q-ST-70-04 and selecting the following test conditions:

1. 100 cycles,
2. vacuum of 1,5 × 10^{-3} Pa, and
3. cycles between –100 °C to +100 °C

c. Adhesion properties shall be measured according to ECSS-Q-ST-70-13 resulting in no signs of anodizing lifting from the substrate

d. Thickness shall be measured to verify that it is in accordance with process requirements.

   NOTE 1 Additional acceptance tests can be specified in order to evaluate the finish of the work-piece or test piece:
   1. vibration;
   2. radiation;
   3. cleaning;
   4. outgassing;
   5. humidity;

6. thermal shock;
7. salt spray;
8. electrical resistivity.

NOTE 2 The tests are preferably performed according to relevant ECSS documents (see ECSS-E-ST-10-03).

e. The acceptance shall be performed at all locations representative of the work-piece.

5.6.3.3 Welding

a. Electrical grounding shall be applied during most of welding processes.

NOTE The welding process determines the necessity of electrical grounding.

b. The anodic coating shall be ground away where the weld is applied.

NOTE This action results in a very disturbed zone around the welding area.

c. Black- anodized parts shall not be welded.

d. If agreed by the customer, where black-anodized surfaces are welded, the process shall be verified.

e. The welding process shall be verified during production with dedicated engineering samples.

5.6.3.4 Repairing

a. Repair procedures shall be qualified to meet anodized surface properties after repair.

b. Before performing repair activities, the process shall be verified by engineering samples.

NOTE The growth mechanism of the anodized layer is a complex process and coatings can have different morphologies.

5.7 Quality assurance

5.7.1 General

a. The quality assurance requirements shall be in conformance with ECSS-Q-ST-20

5.7.2 Specific requirements

5.7.2.1 Data

a. Quality records and logbooks shall be retained for ten years and contain the following information:

1. copy of final inspection documentation;
2. index of limited-life articles and their use times;

3. non-conformance reports and corrective actions;
4. copy of the inspection and test results with reference to the relevant procedure, personnel, tools, equipment and baths;
5. an event log which is a chronological history of process operations and parameters, inspections and tests;
6. details of failure mode (if applicable).

5.7.2.2 Nonconformance

a. Nonconformances of the process shall be dispositioned in conformance with the quality assurance requirements of ECSS-Q-ST-20.

5.7.2.3 Calibration

a. Reference standards and measuring equipment shall be calibrated.

b. Equipment failure shall be recorded as a project non-conformance report.

NOTE Based on failure reports previous results can be examined to ascertain whether re-inspection and re-testing is required.

c. The customer shall be notified of the non-conformance details.

5.7.2.4 Traceability

a. Traceability shall be maintained throughout the process from incoming inspection to final test.

b. Traceability records shall include details of test equipment and personnel employed in performing the task.

5.7.2.5 Operator and Inspector training and qualification

a. Trained and competent personnel shall be employed for all operations and inspections related to the black- anodizing process.

b. Records shall be maintained of the training and qualification status of the operators and inspection personnel.

Annex A (informative) Recipes for aluminium treatment

A.1 Introduction

The Annex describes two techniques for black- anodized aluminium alloys. When the described processes are applied, the coating may not always meet all requirements. Using the know-how of the surface treatment companies may, however, increase the process reliability.

Process procedures are covered in detail in A.2 to A.6, while process summaries are provided in Table A-3 to Table A-3.

A.2 Utilities

The following utilities should be used for the process:

a. Chemical bath(s) capable of:

1. containing the corrosive solution processes,
2. accommodating the work-piece,
3. maintaining the solution temperatures:
   (24 ± 2) °C
   (25 ± 2) °C
   (45 ± 2) °C
   (93 ± 2) °C
   (99 ± 1) °C
4. air agitation of the solution.

b. Ultrasonic bath capable of accommodating the work-piece.

A.3 Hazards, health and safety precautions

a. Materials and parts with hazardous characteristics are treated according to ECSS-Q-ST-40.

b. Health and safety precautions are implemented in order to control and minimize hazards to personnel, equipment and materials.

c. Locations of items and controls are such that personnel are not exposed to hazards

Typical hazards are chemical burns, electric shocks, cutting edges, sharp points or toxic atmospheres.

d. Suitable warning and caution notes are provided in process instructions

For example: Instructions for operations, storage, transport, testing, assembly, maintenance and repair

e. Distinctive markings are implemented on hazardous items, equipment and facilities.

The type of hazard for each material used in the process is given in Table A-1.

Table A-1: Chemical species and associated hazard

Item no.	Description	Type of hazard
1	Trichloro-ethylene	Harmful
2	Trisodium phosphate, $Na_3PO_412H_20$	Harmful
3	Sodium carbonate, Na_2CO_3	Harmful
4	Nitric acid, HNO_3	Corrosive, oxidizing
5	Sulphuric acid, H_2SO_4	Corrosive
6	Deionized water	-
7	Cobalt acetate (reagent grade)	-
8	Ammonium hydrosulphide (reagent grade)	Corrosive
9	Nickel acetate (reagent grade)	Harmful
10	Boric acid	-

Harmful: Substances can have limited effects on health and should not be inhaled, swallowed or absorbed through the skin.

Oxidizing: Substances produce highly exothermic reactions in contact with other substances, especially flammable or combustible materials. Separation from other hazardous substances and use in no-smoking zones should be observed.

Corrosive: Substances can destroy living tissue and contact with the skin shall be avoided.

NOTE The list is not exhaustive. Other chemical products can be used instead of those indicated, e.g. sodium hydrosulphite instead of ammonium hydrosulphide.

A.4 Surface preparation

Parts are cleaned immediately before anodizing and in the following sequence:

a. Vapour degreasing in trichloro-ethylene for 30 minutes.

b. Etching in a solution of:

—	Trisodium phosphate	$Na_3PO_412H_20$	12,5 g/l
—	Sodium carbonate	Na_2CO_3	6,2 g/l

The temperature of the solution should be held at (93 ± 2) °C with a part-immersion time of 5 minutes.

c. Rinsing with water.

d. Desoxidizing for 3 minutes at room temperature in a 50 volume percent solution of nitric acid in water.

e. Rinsing with water.

f. Removal of all residues before anodizing by scrubbing or ultrasonic cleaning.

g. Visual inspection of the work-piece to check the absence of residues or particles.

h. Complementary cleaning procedure, if residues or particles are found.

For example: Ultrasonic cleaning or scrubbing.

i. Thorough rinsing in deionized or distilled water.

The above cleaning sequence can be performed using different solutions from the ones indicated, provided that the prepared surface is fully degreased, etched, and free of particles and residues.

A.5 Anodizing process set-up

A.5.1 Hardware

a. Cathode materials should be either lead or aluminium.

b. Any metallic part of a suspension device that makes contact with the electrolyte is of aluminium or titanium.

c. Work-pieces are suspended in such a way that good electrical contact is maintained throughout the treatment.

A.5.2 Anodizing bath composition

a. The anodizing electrolyte consists of a solution of sulphuric acid 150 g/l in deionized or distilled water.

b. During the lifetime of the electrolyte, the solution is kept within the limits given in Table A-2.

Table A-2: Anodizing electrolyte composition limits.

Chemical species	Requirement
Sulphuric acid H_2SO_4	120 g/l to 180 g/l
Chloride	Lower than the equivalent of 0,2 g NaCl/l
Aluminium content	Lower than 3 g/l
Fluorine content	Lower than 0,001 g/l

A.5.3 Experimental parameters

A.5.3.1. Temperature

a. The bath temperature during anodizing is kept within the manufacturer's specification.

b. Air agitation of the electrolyte should be sufficient to keep the specimen to electrolyte temperature difference below 0,5 °C.

A.5.3.2. Current

Current density is between 1 A/dm^2 and 2 A/dm^2.

A.5.3.3. Duration

Anodizing time is set to give a thickness of the anodic film that fulfils the project requirements in terms of surface optical properties, corrosion and wear resistance.

Typical thickness range from 10 μm to 35 μm. The thickness can be estimated from the following formula:

$$\frac{(current\ density)(time)}{3{,}22} = thickness$$

where:

— current density expressed in A/dm^2

— time expressed in minutes

— thickness expressed in μm

A.5.3.4. Cleaning

Immediately after removal from the bath, the parts are washed to remove the electrolyte, and finally rinsed with deionized water.

A.6 Dyeing and sealing process

A.6.1 General

Dyeing operations follow immediately after cleaning described in A.5.3.4 to avoid lowering the absorptive capacity of the film.

Dyeing can be delayed up to a maximum of 1 hour, if the anodized parts are kept in cold deionized water.

A.6.2 Cobalt sulphide black dying process

A.6.2.1. Solutions

Three bath solutions are used, which consist of:

a. A solution in de- ionized water of 200 g/l reagent-grade cobalt acetate to be heated to (45 ± 2) °C.

b. A solution in de- ionized water of 30 g/l reagent-grade ammonium hydrosulphide, maintained at (24 ± 2) °C.

c. A solution of 5 g/l nickel acetate and 5 g/l boric acid
   1. maintained at a temperature of (99 ± 1) °C;
   2. with a pH value of 5,5 to 5,8.

A.6.2.2. Procedure

a. The wet parts are immersed in the cobalt acetate solution, maintained at (45 ± 2) °C, for 15 minutes.

b. The work-pieces are then rinsed with deionized water to remove excess cobalt acetate solution.

c. Immediately thereafter, the work-pieces is immersed in the ammonium hydrosulphide solution at (24 ± 2) °C until a deep black coloration is attained.

   This takes between 5 minutes and 15 minutes.

d. Immediately afterwards, the parts are sealed by immersion in the solution of nickel acetate and boric acid at (99 ± 1) °C and pH 5,5 to 5,8, for 25 minutes.

A.6.3 Nickel sulphide black dyeing process

A.6.3.1. Solutions

Two bath solutions are used, which consist of:

a. A solution in de- ionized water of 50 g/l reagent-grade nickel acetate; maintained at (25 ± 2) °C.

b. Ammonium hydrosulphide 25 %.

A.6.3.2. Procedure

a. The wet parts are immersed in the nickel acetate solution at (25 ± 2) °C for 3 minutes.

b. The work-pieces are then rinsed with deionized water to remove excess nickel acetate solution.

c. Immediately thereafter, the work-pieces are immersed in ammonium hydrosulphide for 3 minutes.

d. The work-pieces are rinsed with deionized water.

e. Steps b. to d. are repeated until the parts are deep black.

This takes normally 3 to 5 dips.

f. The parts are sealed by immersion in boiling deionized water for 25 minutes.

A.7 Process summary

Process steps as summarized in Table A-3 to Table A-6 may be followed instead of the detailed steps in A.4, A.5, A.6.2 and A.6.3.

Table A-3: Summary of pre-treatment (see A.4)

Process step	Solution composition	Required conditions
Vapour degreasing	Trichloro-ethylene	30 min
Etching	Trisodium phosphate 12,5 g/l Sodium carbonate 6,2 g/l	(93 ± 2) °C 5 min
Rinsing	Deionized water	
Desoxidizing	50% nitric acid in water	3 min
Rinsing	Deionized water	
Cleaning	-	Scrubbing / ultrasonic
Rinsing	Deionized / distilled water	

Table A-4: Summary of anodizing (see A.5)

Process step	Solution composition	Required conditions
Immersing	Sulphuric acid 150 g/l in deionized / distilled water $[Cl^-]$ < equivalent 0,2 g NaCl/l $[Al^{3+}] < 3$ g/l $[F^-] < 0{,}001$ g/l	Temperature within manufacturer's specification $1 < J < 2$ A dm^{-2} Time set to reach 25 to 35 µm thickness (see A.5.3.3)
Rinsing	Deionized water	-

Table A-5: Dyeing with cobalt sulphide (see A.6.2)

Process step	Solution composition	Required conditions
Immersing	200 g/l cobalt acetate in deionized water	(45 ± 2) °C 15 min
Rinsing	Deionized water	Remove excess cobalt acetate
Dyeing	30 g/l ammonium hydrosulphide in deionized water	(24 ± 2) °C until deep-black colour (5 min to 15 min)
Pore sealing	5 g/l nickel acetate, 5 g/l boric acid	(99 ± 1) °C 5,5< pH < 5,8 25 min
Dyeing commences within 1 hour after anodizing.		

Table A-6: Dyeing with nickel sulphide (see A.6.3)

Process step	Solution composition	Required conditions
Immersing	50 g/l nickel acetate in deionized water	(25 ± 2) °C 3 min
Rinsing	Deionized water	Remove excess nickel acetate
Immersing	Ammonium hydrosulphide 25%	3 min
Rinsing	Deionized water	-
Repeat above steps until part is deep black (3 to 5 times)		
Pore sealing	Deionized water	Boiling 25 min
Dyeing commences within 1 hour after anodizing.		

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ECSS-E-ST-10-03	Space engineering – Testing
ECSS-Q-ST-40C	Space product assurance – Safety