Thermo-optical coatings for space applications

Strategy for UV-Stable Coatings for Satellites

- **Challenge:**
  - Conventional paints and established coatings failed in ESA's thermal UV vacuum chamber tests.
  - **Issue:** Either **coatings peeled off** or **turned black** due to:
    - **Decomposition of silicone binders**
    - **High brittleness** due to unsuitable compositions
    - **Evaporation of components**
- **Our Solution:**
  - **Organic-free, highly white coating system**
  - **Cures at room temperature**, sinterable up to **500°C in air**
  - **Substrate pre-treatment:** Only sandblasting and degreasing, no chemical pre-treatment
  - **Starting point:** Existing release coatings
- **Development Timeline:**
  - **2009:** First prototypes and pre-tests in the lab
  - **2011:** Final product, small-scale tested, moved into ESA qualification cycle → **Space Coating NV14**
  - **2012-2016:** Testing, audits, upscaling, and contamination problem-solving
  - **2018: Mission launch** (after multiple delays)

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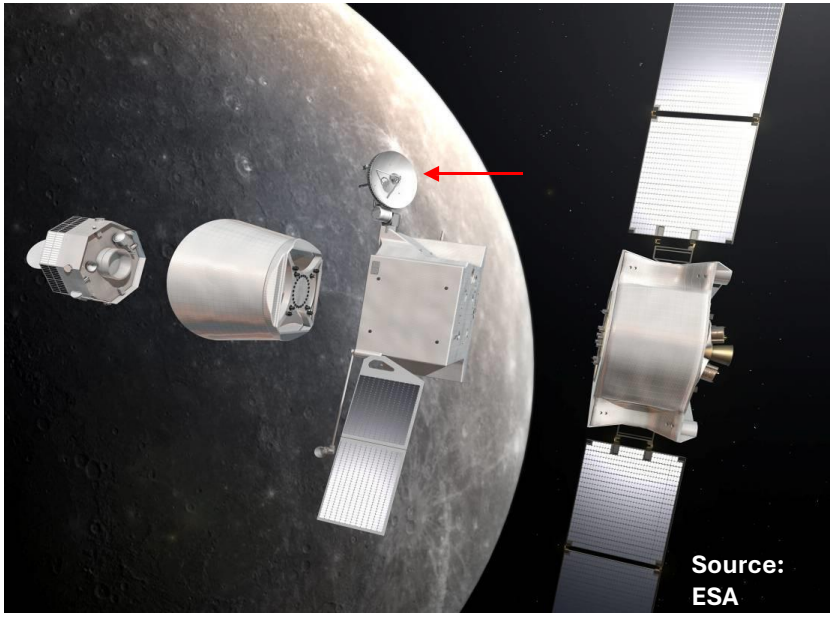
NV14 White, reflecting ceramic coating for satellites in outer space

Resistance against

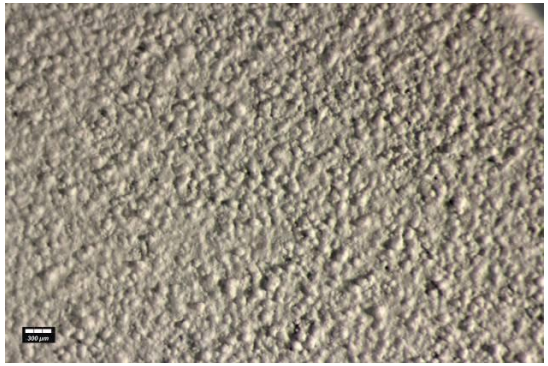
- Thermal shocks between -200°C (-270F) and 500°C (840F)
- Intense UV ray exposure

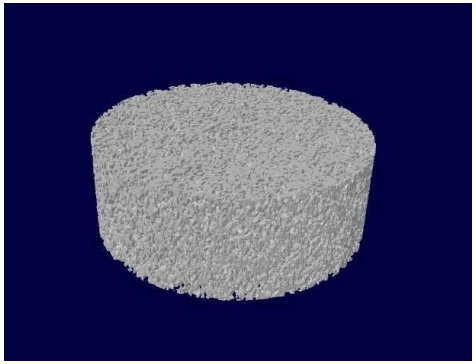
REACH conformity (harmless chemistry)

Remains white under harsh conditions (determined by simulation tests under high vacuum, high temperature and high UV load (11 solar constants) over several years.



Substrates: titanium, titanium foils and aluminum, CFRP, steel





Ceramic Coating NV14: Composition and properties of coating constituents

Al_2O_3	→	dull, white abrasion resistant
h-BN	→	dull white, flexible, good thermoshock
Potassium silicate	→	reflective binder
C-Content	→	Zero organic C

Variations with improved conductivity under development

- Aqueous coating NV14/ACF to be applied on several substrates esp. on (blasted) TiGrade5 /TiGrade 2 and Aluminium surfaces (0.02mm: 0.1 mm - several mm thickness), steel, CFRP also possible
- Coating is applied manually via low pressure spraying technique and can be used for complex 3-dimensional geometries, proven up to 600x700cm in size
- Coating needs drying and can optionally be dewatered at 500°C for one hour (NV14) under air if needed. Ambient curing= NV14 ACF; chemically and process wise identical
- Optionally: Coating can be sealed with a thin glass like layer and can be cleaned with UV/O3 in case of contamination (for Titanium substrates)
- Coating is ATOX stable (life time test for EnVision under way)
- Coating is used by ESA and its European industry partners on the BepiColombo and SolO space mission; also first application on ISS in 2018, planned MSR and Envision

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Thermo-optical properties:

Excellent $\alpha/$ values before and after life cycle test of 28.000 ESH (equivalent sun hours) and 430°C under vacuum (200nm -400nm UV Intensity : 11 ± 2 solar constants acc. to ECSS-Q-70-09A) IR- range also covered Test performed by ESTEC

α/ε: before test:	0.25 with α: 0.2 and ε: 0.8
α/ε: after test;	<0.4 with α: 0.34 and ε: 0.87

- Fully diffusive, porous, coating with no detectable specularity
- α down to 0.1 depending on layert thickness (up to 100µm possible)
- Pores can be sealed with a sol-gel glass like sealing in combination with UV/O3 cleaning
- Cleaning alone with O3/UV is also possible
- Very good adhesion to substrate ; tape test with peel strength > 220 g/cm after 28.000 ESH UV exposure passed (according to ASTM D 3359 or equivalent)
- Very good thermo shock resistance and ductility: exposure to -200°C up to ca. 450°C in <10 minutes is easily possible
- Coating thickness tunable between 10 and 100 µm with an accuracy of +- 5 µm
- Suitable substrate types are: Ti6Al4V, Ti, CFRP, and also Niobium C103 and C/SiC;Copper, steel, aluminium; for metal sand blasting optional
- T_{max} in vacuum at least: 550°C

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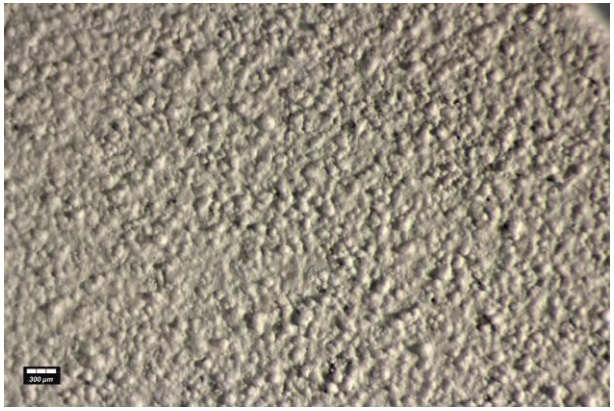
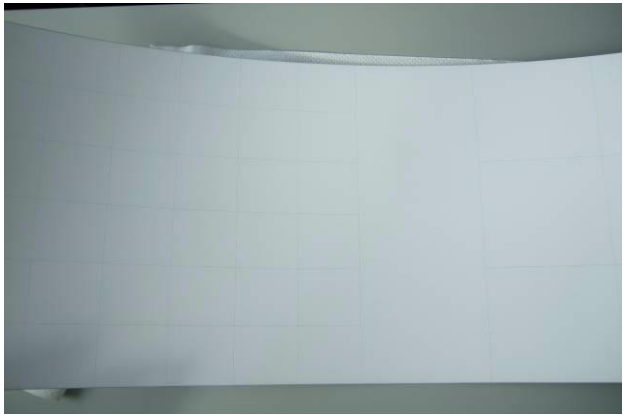
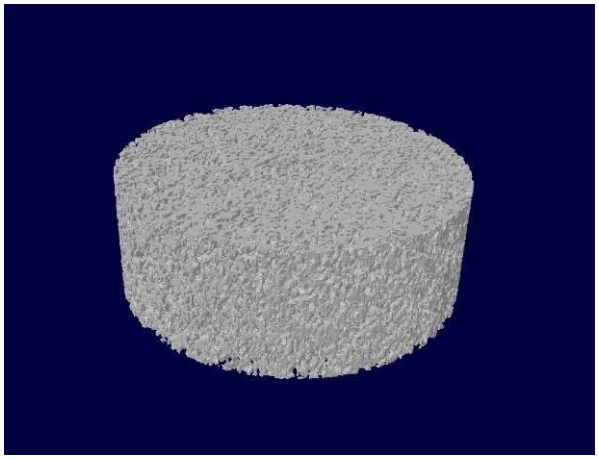
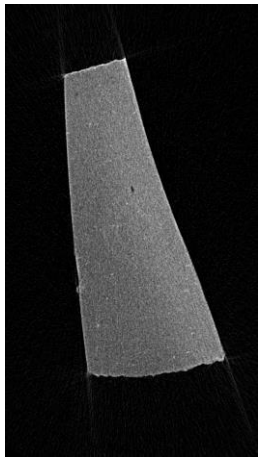


White ceramic with regular microroughness

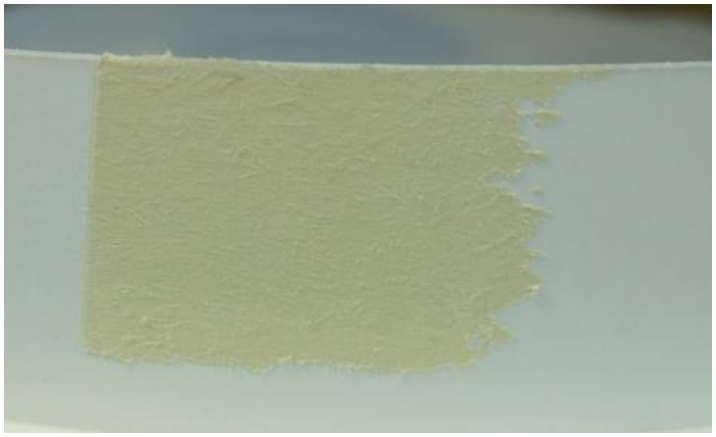


ESD: Partly removal of NV14 possible → mechanical grid





µ-CT pictures (calculated and measured) showing highly porous structure of NV14



Tape test on NV14 → excellent adhesion with delamination of tape with peel strength > 220 g/cm

Parts:

- HGA Antenna inkl. sub-reflectors
- HDRM mechanism (Hold Down Release Mechanism)
- Solar array, edge shields
- Instrument covers
- Heat Thruster Shield
- MLI Titanium foils
- Solar screen at Estec (3x)
- ISS Muses platform

Projects

- Application on NV14 on Al, CFRP, Kapton
- Contamination repellent coatings
- White conducting coatings

Executive summary:

- Ceramic coating NV14 is a highly UV and temperature stable ceramic white coating for applications on Titanium alloy parts for space applications
- It is applied manually by spraying and can by ambient cured or as an alternative dewatered at 500°C for one hour under air to solidify (for titanium or sealing)
- The coating remains very white under hard UV irradiation in clean atmosphere and diffusively reflects electromagnetic radiation from 200 nm to several µm without being damaged.
- The highly porous coating has excellent thermoshock resistance properties, adhesive power and does not gas out under vacuum, radiation and high temperatures.
- Coating can be sealed with a thin glass like layer and be cleaned with Ozone/UV to avoid contamination whilst keeping all its thermooptical and adhesion properties
- Electrically conducting white coating is under development
- The coating passed all tests mandatory by ESA for BepiColombo/SOLO mission approval. It is also used on ISS and under evaluation in MSR