

A glance in Conservation Science. Chemical-physical mechanisms in cleaning art surfaces



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The Cleaning Issue

01

Soiling Typology

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...the cleaning issue

Cleaning controversy: a never ending story.



Definition

removal of undesired material from the surface and near-surface region

Cleaning

EN 1738:2018

Conservation of Cultural Heritage - Methods and materials for cleaning porous inorganic materials

Requirements

Selectivity
Control
Graduality
Safe for the environment

Aims

- effective in removing all the dangerous substances able to induce decay in the object
- not harmful as to the substrate.
- avoiding dangerous by-product
- respectful as to natural patina and intentional finishes

...the cleaning issue

why Cleaning ?
is the object decayed ?

what is the best cleaning method for the object ?
which are the chemical-physical features of the object ?
is the treatment fitting the cleaning requirements ?
how does the treatment work ?
is the treatment safe for the operator ?
is the treatment dangerous for the environment ?

what will be the final aspect of the cleaned object ?
when stop ?
how much insist ?
is the stability of the object endangered ?
how often will be cleaned the object ?



02

Soiling Typology

Ho su di me la polvere dei secoli. Chi sono io per profanar la storia?
Pig-Pen Peanuts



Soiling Typologies


- black crusts
- encrustations
- lime-washes
- old treatments residues
- biological patinas
- soluble salts
- graffiti
- colored stains
- particulate matter
- tarry soot
- old varnishes
- over-paintings
- corrosion products



03

Cleaning Methods

Mechanical, Chemical, Physical.



Cleaning System



- **Mechanical methods:** lancet, brushes, dry or wet micro-sandblasting
- **Water methods:** nebulised spray, water based poultices
- **Chemical methods:** solvents, surfactants, chelators, Ion exchange resins
- **Biocleaning:** cleaning with living organisms
- **Laser Cleaning:** Nd:YAG, Er:YAG
- **Gels:** agar, gellan Gum, alginate, synthetic polymers

04

Laser Cleaning



Laser Fundamentals

A **laser** source can produce ultraviolet, visible or infrared emission
laser emission used in CH

pulsed (pulse duration ms – **Normal Mode**),
flash (pulse duration ns – **Q-switched**)

QS - LQS - SFR

λ Wavelength

UV (0.2-0.4 μm) VIS (0.4-0.7 μm) IR (0.7-10 μm)

t pulse duration (ms, μs , ns)

E pulse Energy (Joule) power (Watt)

F Fluence or Energy Density (J/cm^2)

LASER Nd:YAG

Solid state Laser

λ

1064 nm or 532 nm

Q-switched regime

(30 Hz frequency)

Pulse duration 7 ns

E Energy per pulse 1 J

Laser Cleaning Devices



Nd:YAG

1064 nm
QS
LQS
SFR



Nd:YAG

532 nm
QS



Er:YAG

FR 2.94 μm
 $t = 150\text{-}250 \mu\text{s}$



Excimer

308 nm, 248 nm, 193 nm



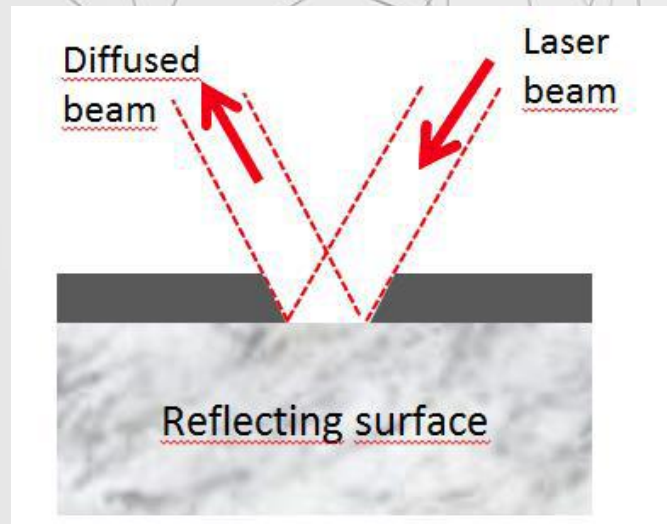
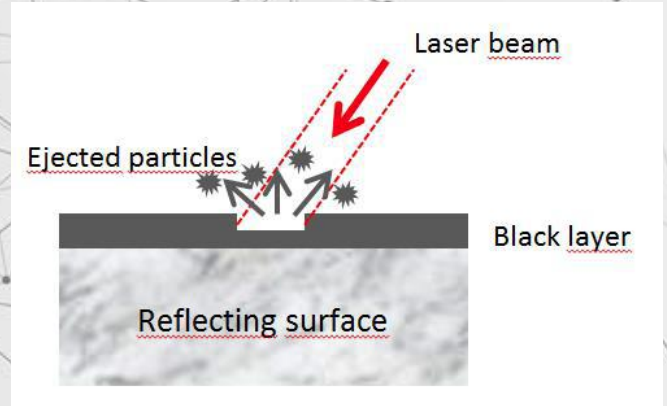
TEA CO₂

10.6 μs



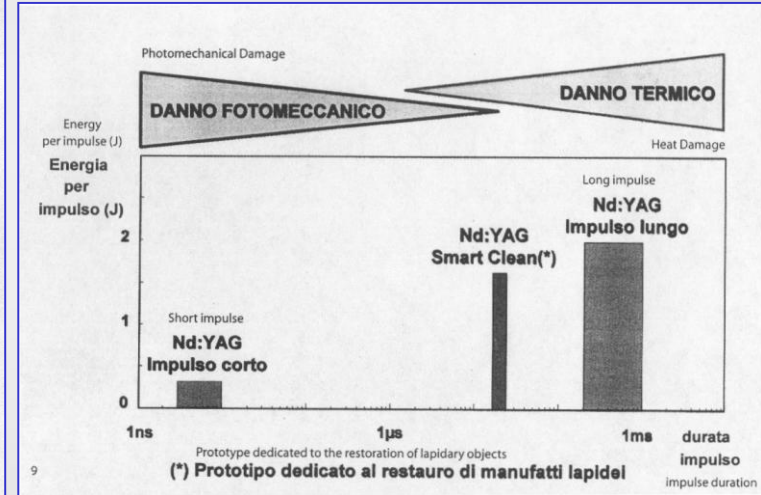
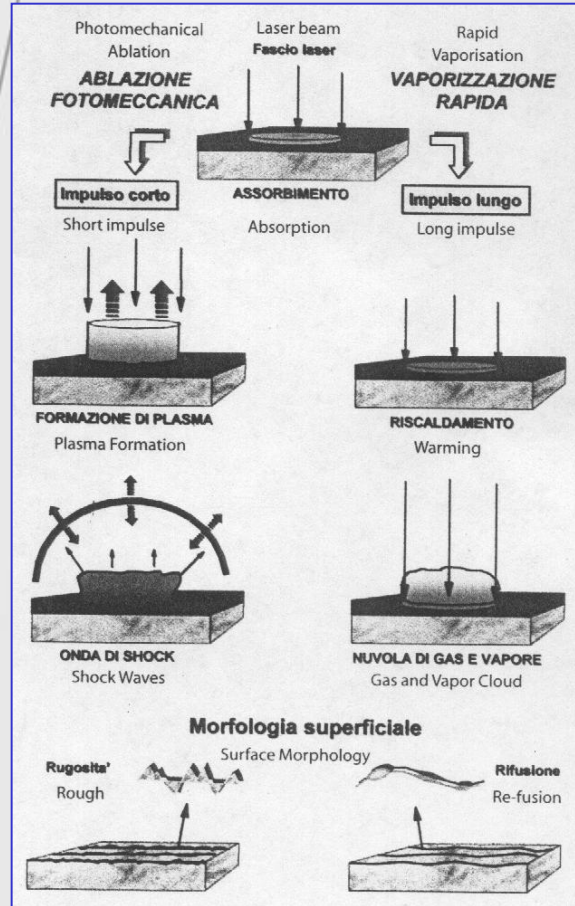
Main laser cleaning mechanisms

- Selective evaporation of black crusts
- Action of rapidly expanding vapors
- Thermal and photodecomposition of layers
- Removal of small adherent particles
- True ablation (varnishes and paints)
- Delamination by thermal expansion
- Spallation by laser induced shock wave





Main laser cleaning mechanisms



Laser Cleaning

Benefits	Drawbacks
Non Contact Process	Pigments sensitivity (lead white, cinnabar, minium)
Selective and Versatile process	Possible yellowing
Process ceases shortly after the laser pulse	High costs
Controllable – specific thickness of material can be removed	Specialized staff
Environment safeguard	
Water assisted conditions	

The Yellowing issue...



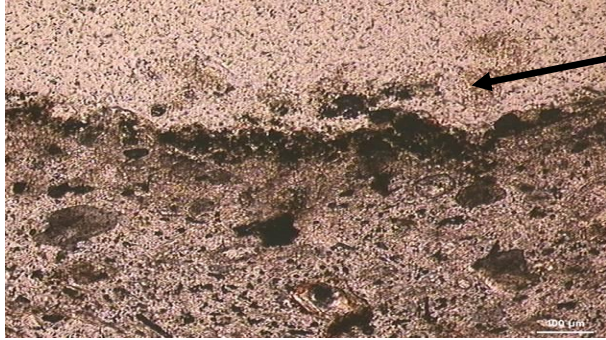
Border soiled-cleaned 450 mJ/cm²
(bar = 1mm)



Border soiled-cleaned 475 mJ/cm²
(bar = 1mm)

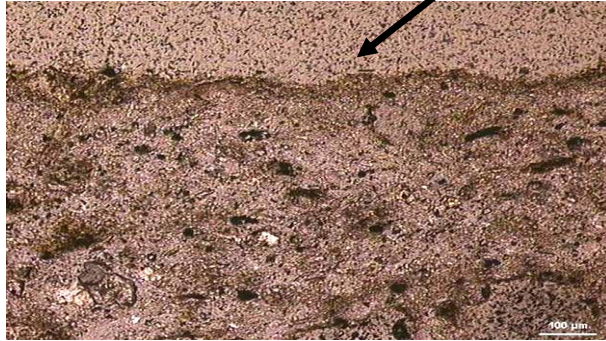


The Yellowing issue...

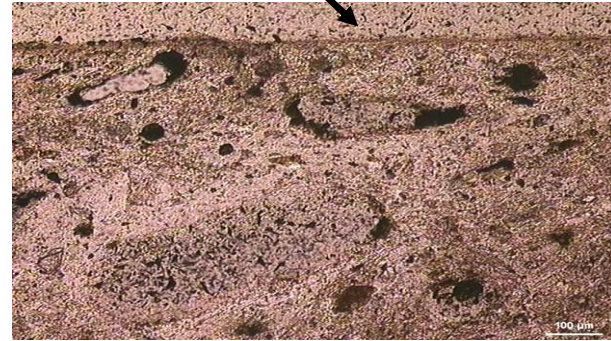


Soiling before cleaning
(nicol 45°, bar = 100mm)

Ochraceous Film after cleaning.
(nicol 45°, bar = 100mm)



450 J/cm²



475 J/cm²

Masterpieces cleaned with laser



www.theacropolismuseum.org



Festa et al. 2009 j Appl. Physics



Sansonetti et al. 2016 Microchem. J



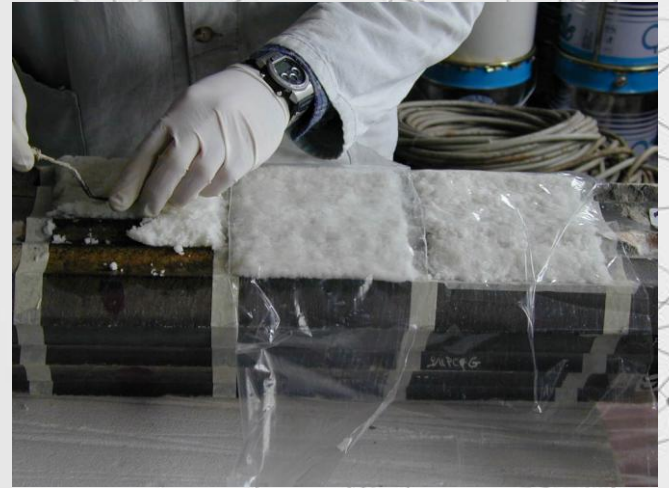
05

Gel Cleaning

A variation of chemical poulitice



- thickening systems: clay, cellulose fibers, alumina
- fluid composed by solvents or chemical formulation
- used in removing soluble salts
- swelling aged decayed layers
- control of the contact time
- control of fluid release



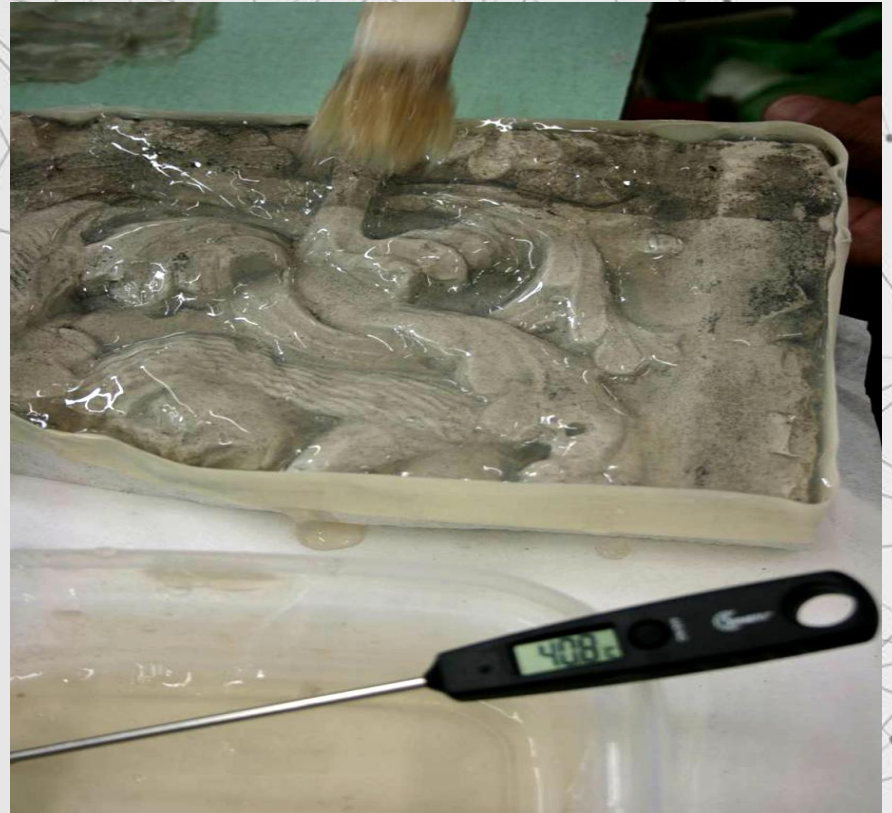
agar gel



- polysaccharide from red algae Rhodophyta (species Gelidium & Gracilaria)
- composed mainly by Agarose and Agaropectine
- rigid thermo-reversible gels
- sol T 83/93°C
- gel T 30/40°C
- pH solution 1% 6,0/8.0

when using agar gels
it is possible to vary:

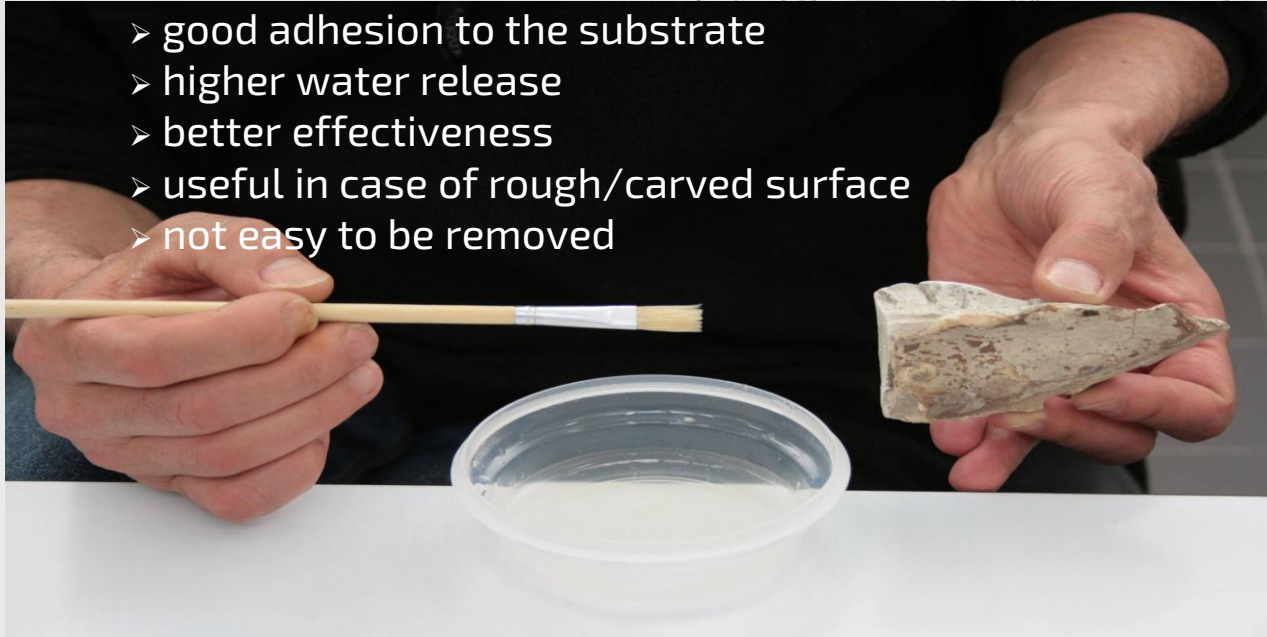
- agar type
- solution %
- application
- temperature
- thickness
- contact time



fluid gel: images courtesy of Aconerre Milan

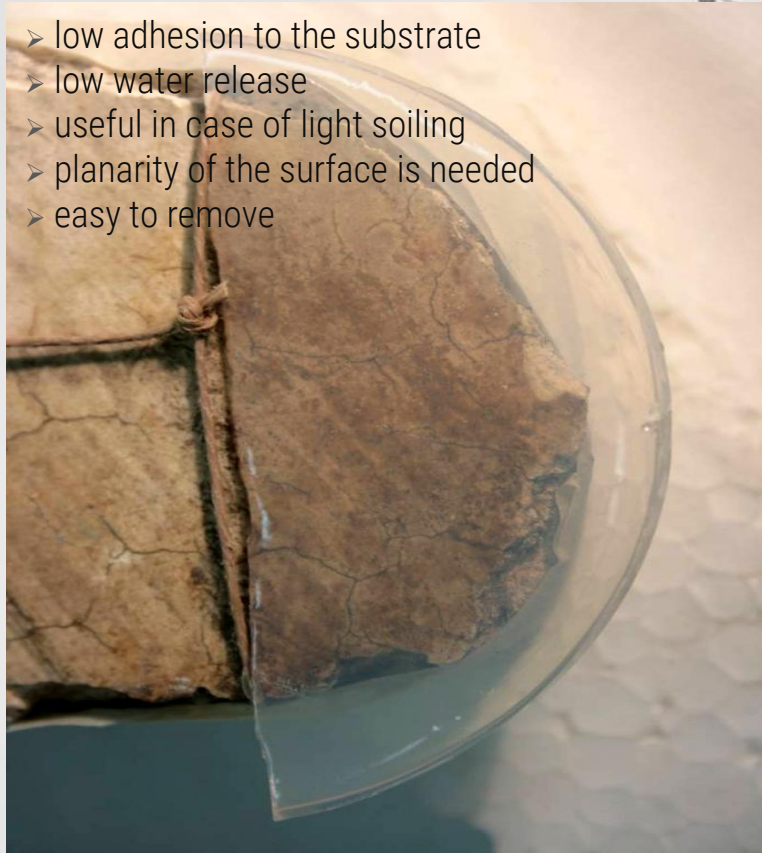
fluid agar application

- good adhesion to the substrate
- higher water release
- better effectiveness
- useful in case of rough/carved surface
- not easy to be removed

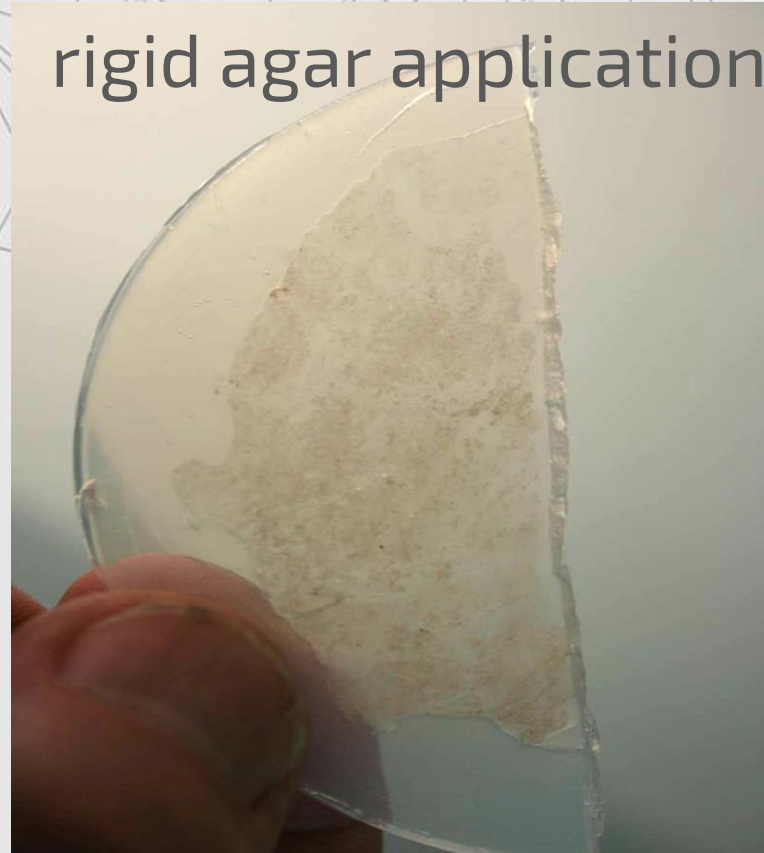


fluid gel: images courtesy of Aconerre Milan

- low adhesion to the substrate
- low water release
- useful in case of light soiling
- planarity of the surface is needed
- easy to remove

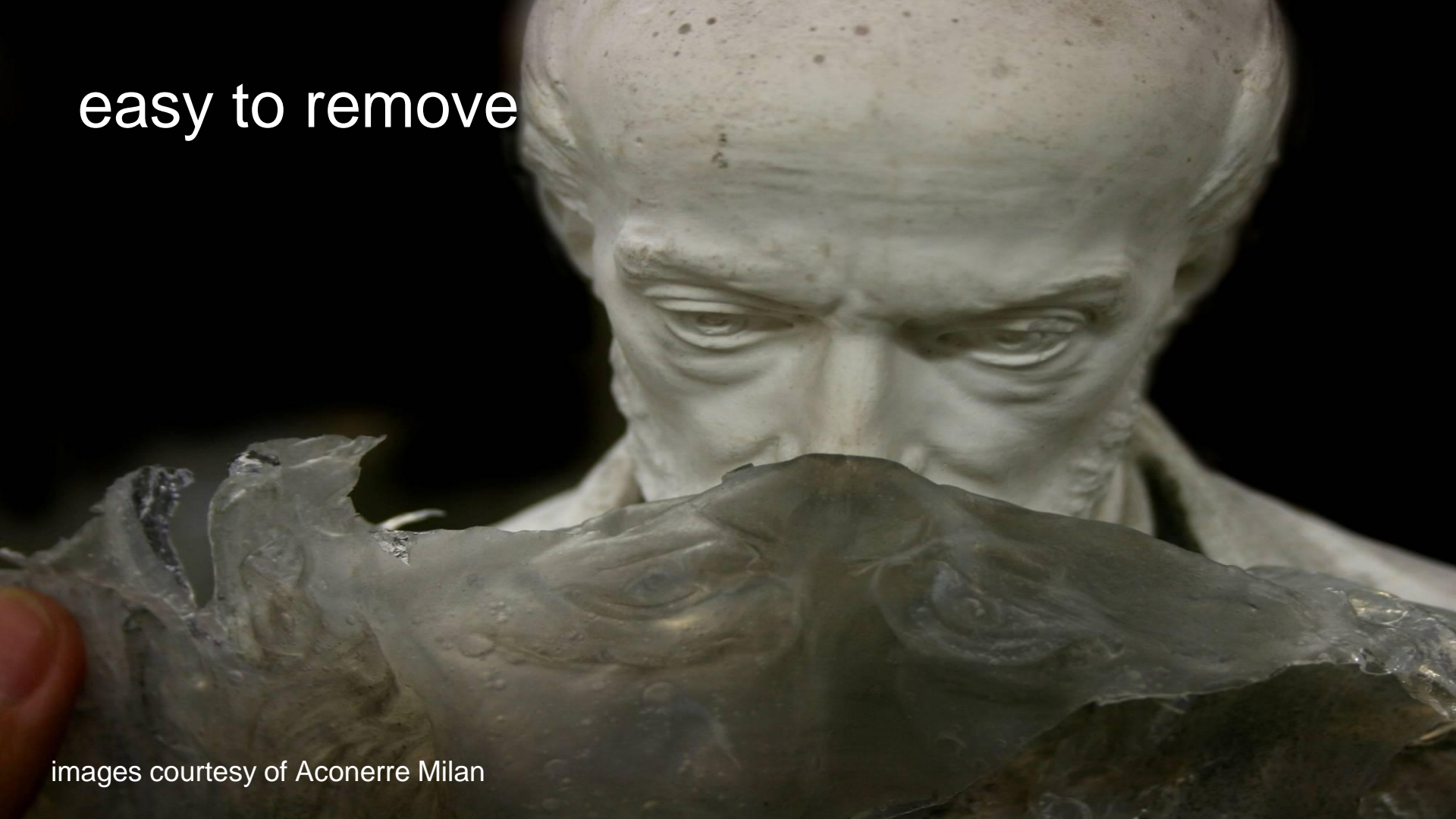


rigid agar application



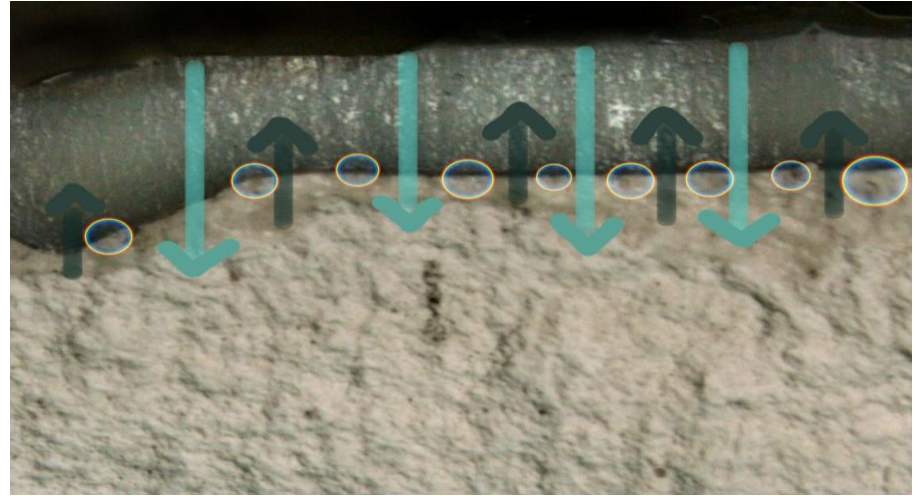
rigid gel: images courtesy of Aconerre Milan

easy to remove



images courtesy of Aconerre Milan

agar gel action in desalination



1 { release of water
diffusion of the solute

2 { suction mechanism
back transportation of the solution when the gel is drying
peeling of the gel loaded with soluble salts

Sala delle Asse Leonardo da Vinci. Milan Sforza Castle



Desalination and Cleaning

Sala delle Asse Leonardo da Vinci. Milan Sforza Castle. Desalination



Pads at different porosity

Poultice prepared with:

- Clay
- Paper pulp
- Wood pulp
- Agar

Other gel materials:

- Gellan Gum
- Acrylic polymers
- Modified Vinyl polymers

Antonio Canova Napoleon Statue. Brera Courtyard



06

Open Problems



Possibility to combine laser + agar gel

- particular stains
- use in case of sensitive materials
- use agar gel as a wetting agent
- limiting water release
- Avoiding fall-out of ejected particles

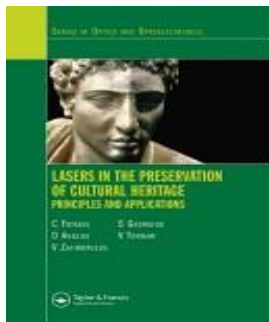


Contribute of physical science

- Tests with new laser sources
- Tests with ultrashort pulses
- Tests with lasers with variable pulse length
- Proposing new protocols for evaluating cleaning effects
- Better understanding of desalination mechanisms
- Formulate gels and poulticing with tunable properties

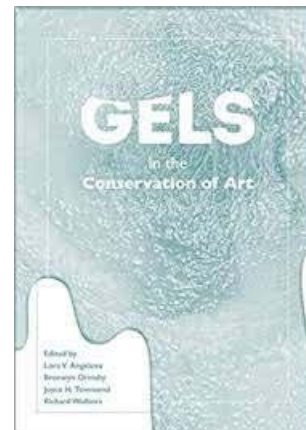


Main References

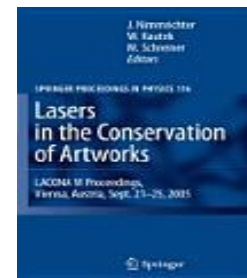
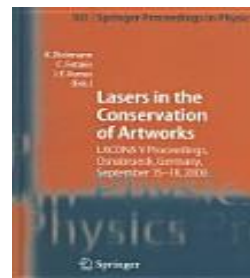


Aplar
APplicazioni Laser nel Restauro

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Lacona Proceedings





THANKS

Does anyone have any questions?

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