Natural, safe and costeffective virucidal technology for PPE

Molecular plasma coatings for biomedical applications



M. Milani / B. Nisol – March, 2022

Pandemic problem with face masks and PPE mp

- Accidental contamination by touching masks exposed to virus
- Masks have to be changed often because of contamination

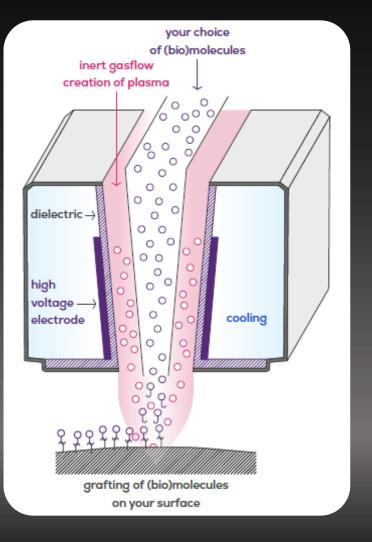


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PLASMALINE® - INDUSTRIAL SOLUTION FOR COATING

✓ Activation of surface

- \checkmark Activation of precursor
- ✓ Controllable flows
- ✓ Managed energy
- \checkmark Binding to surface
- ✓ Cross-linking (if wanted)
- \checkmark In one single step



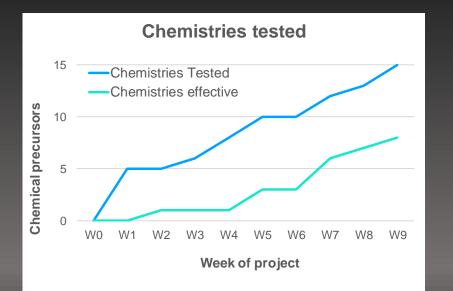
INDIRECT DBD PLASMA

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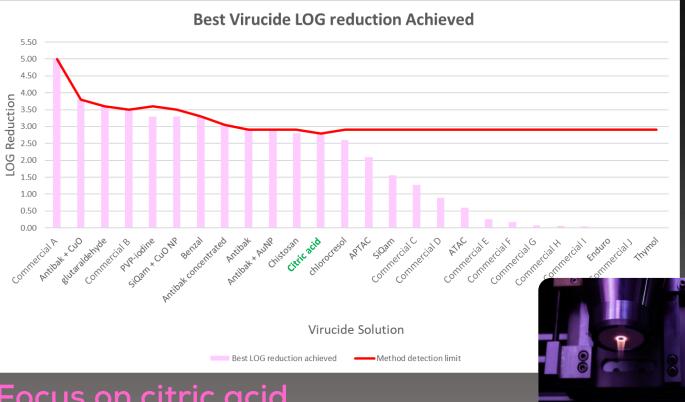
- No arcing
- No fouling of electrodes
- Ambient T
- Continuous, atmospheric press
- Adaptable with nozzles for:
 - Porous structures
 - Wires and fibres
 - Uneven shapes

VIRUCIDAL COATINGS

Wide range of chemistries tested: Pure liquid chemicals Solutions of natural compounds or biomolecules **Commercial biocidal formulations** Drugs/Therapeutic agents



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Focus on citric acid

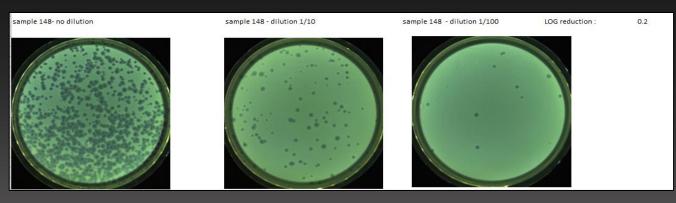
- Excellent virucidal efficacy and non-irritant due to efficiency of plasma coating •
- In the Annex 1 list of European Chemicals Agency for simplified market authorization •
- It is an allowed food additive by the FDA and in Europe (E330) •

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- Not an active pharmaceutical ingredient •
- Surgical facemasks with MPG's citric acid coating are CE certified as medical devices •

MPG's Virucidal coating reduces risk

Untreated facemask fabric



Viruses:

Non-enveloped MS2

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- Enveloped Φ6
 Standards used:
- ASTM E2721-16
- ISO 10705-1:1995

Facemask fabric with MPG virucidal coating

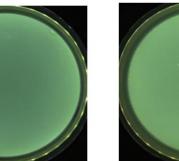


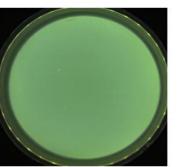
sample 154 - dilution 1/10

sample 154 - dilution 1/100

/100 LOG reduction

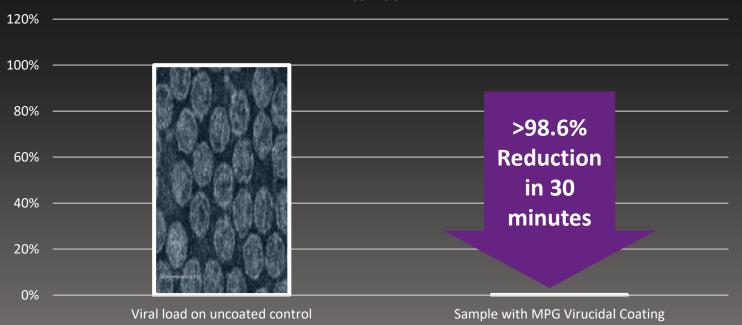
2.8







Proven effective against SAR-COV-2 virus



Plasma Coated Polypropylene Nonwovens

"MPG plasma treatment of non woven fabric (Polypropylene, PP) with Citric Acid decreased SARS-CoV-2 by at least 98.6% at the lowest concentration and by at least 99.4% at the highest concentration. The experiments have reached the limit of detection of the log reduction, indicating that the reduction is likely higher than the reported due to the limited sensitivity of the experiment."

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Efffective, Natural and Safe Virucidal

- Natural, non toxic, environmentally friendly citric acid as virucidal
 - No effect on people, tested and documented biocompatibility
 - Facemask remains class I medical device
 - Less than 10 mg of citric acid per mask
 - Dry, bonded to the surface
 - Affordable
 - No nanoparticles, no persistent metal ions, no additives

Biocompatibility Data



Non-irritant and non-toxic:

Safe even if misused

Verification	Status	Laboratory	Report reference*
Cytotoxicity per ISO 10993-5:2009	Non-toxic	Hohenstein - Germany	20.8.5.1280
Skin Irritation OECD 439	Non-irritant	Abich - Italy	REL/3971/2020/IRRC/ELB
Mucosa Irritation in-vivo ISO 10993-10:2009	Zero irritation even at 10X dose	Icare - France	MJ-PH-20 /0888 /889 /890
	Zero sensitization even at 10X dose	Biochem - Italy	518398_20-1374-0, 518398_20-1375-0, 518398_20-1376-0,
	Zero irritation even at 10X dose	Icare - France	Res-ic-iso-20- -0898 /-889 /-890

Mask Performance Data



• Tested per EN 14683 standard

Facemasks' breathable barrier function is **unchanged**

Verification	Status	Laboratory	Report reference*
Type I/II - Breathability (differential pressure)	PASSED	Icare - France	1541Y-23A
Type I/II - Bacterial filtration efficiency	PASSED	Icare - France	11541Y-2A
The second secon		Customers' choice	Customers' specific models
.,,,		Customers' choice	Customers' CE certification

Stability Data



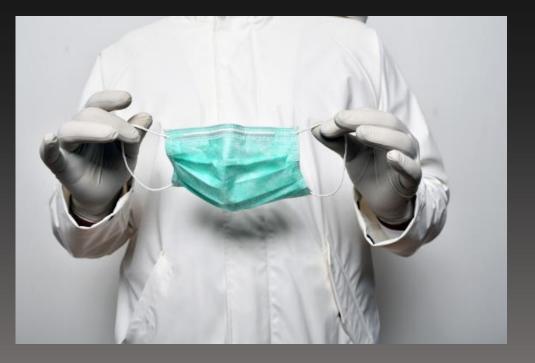
• Shelf life and efficacy studies

Virucidal coating is **stable**: In normal storage conditions

Compliance Requirement	Verification*	Current shelf life statement
	Virucidal effectiveness on PHI 6 enveloped virus after accelerated ageing.	5 years: still >99% effective, when kept in sealed plastic packaging.
	Citric acid has a negligible effect on polypropylene.	Same as original facemask.
	Facemasks with high/low dosis of virucidal coating have passed EN 14683+AC:2019 tests after up to 5 years equivalent of accelerated ageging.	Same as original facemask or up to 5 years.
Biocompatibility	The degradation of citric acid within the expected use of the product should not be of safety concern as these have been considered in similar usage cases by FDA and EFSA in order to allow Citric Acid as food additive. Citric acid is stable below 70 °C.	Same as virucidal function.
Facemask wear time	The effectiveness of the citric acid virucidal coating when exposed to high moisture suffers a slow decay, but it outlasts the recommended 4 hour wear time for single- use face masks dictated by hygiene and/or filtration efficiency parameters.	Same as original facemask.
	Virucidal effectiveness on MS2 virus after real time ageing.	Use within one month from opening sealed packaging.

Increased Safety with MPG Virucidal Coating mpg

- Coating on the outer layer of single use face masks and PPE
- Does not change breathability
- Natural, non toxic, environmentally friendly virucidal
- Using an innovative simple, reliable and safe technology
- Documented results available



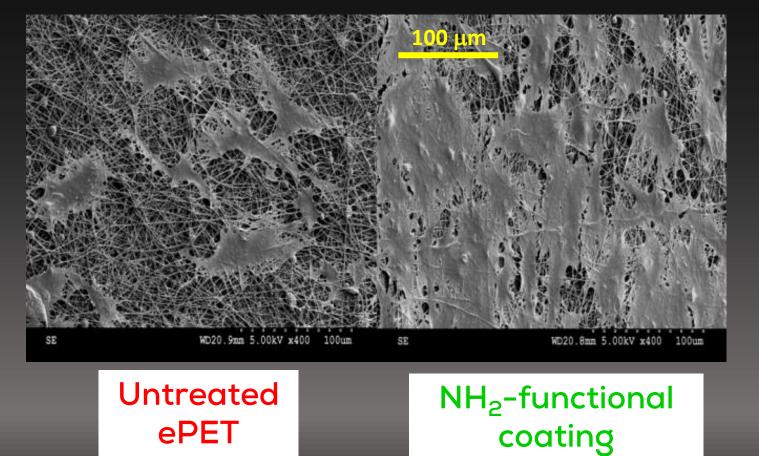
- Enhanced cell growth / adhesion Scaffold engineering and treatment of implants
- Anti-biofouling & Biodegradable To avoid non-specific binding and cell adhesion/growth
- Biomolecule immobilization micro-patterning
 Biosensing applications, point-of-care tests
- Virucidal and antibacterial coatings

• Plasma in liquids (early stage; where allowed)

BIOACTIVE COATINGS



Bioactive surfaces and coatings (implants, 3D cell culture for drug screening)



[1] H. Savoji *et al., Macromol. Biosci.* 2014, *14*, 1084. [2] B. Nisol *et al., Plasma Process. Polym.* 2016, *13*, 965.

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Improved adhesion and growth of vascular smooth muscle cells

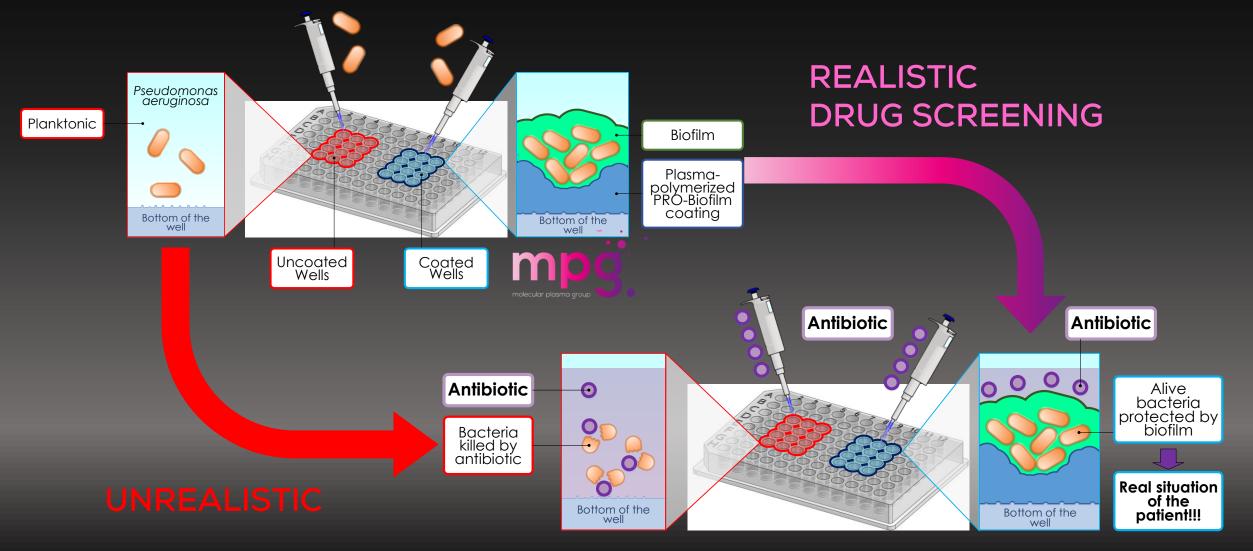
Can be used in:

- 🗸 Implants
- ✓ Scaffolds (3D printed, electrospun)
- ✓ Endovascular prostheses
- ✓ 3D cell culture (drug screening)

BIOACTIVE COATINGS



PRO-BIOFILM COATINGS: ENHANCED CELL/BACTERIA ADHESION AND GROWTH



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E. Sainz-García et al. Applied Surf. Sci. 2022, 581, 152350.

ANTI-FOULING COATINGS



✓ Implants and

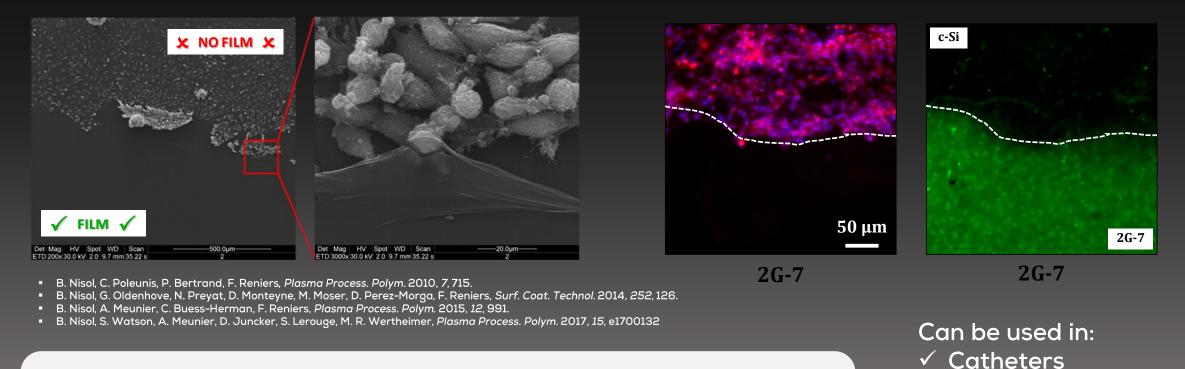
biosensors

✓ Endovascular

prostheses

✓ Microfluidic systems

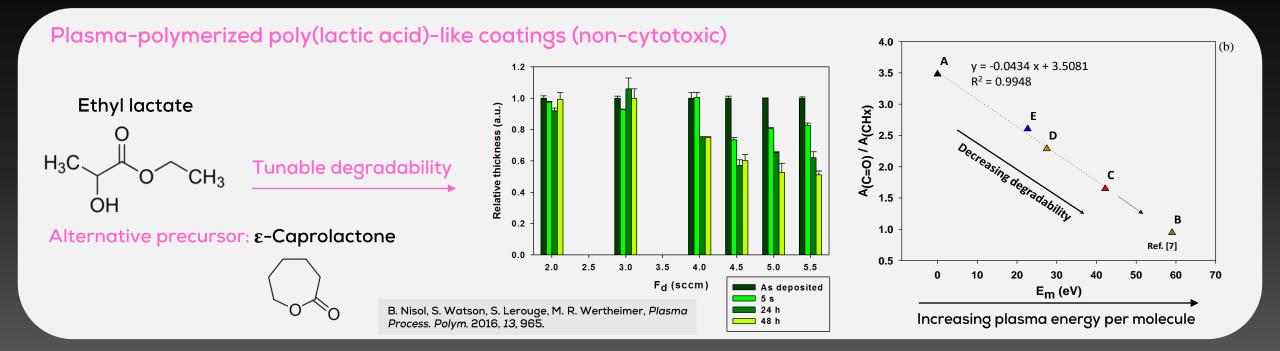
Plasma-polymerized poly(ethylene glycol)-like coatings



"Ghosts" in biological environments:

TOTAL inhibition of protein adsorption and cell adhesion

BIODEGRADABLE COATINGS



APPLICATIONS

- ✓ Controlled drug delivery systems
- ✓ Encapsulation of active molecules (slow release)

Can be used in:

skin patches

 \checkmark

•••

- cardiac patches
- ingestible drug delivery systems

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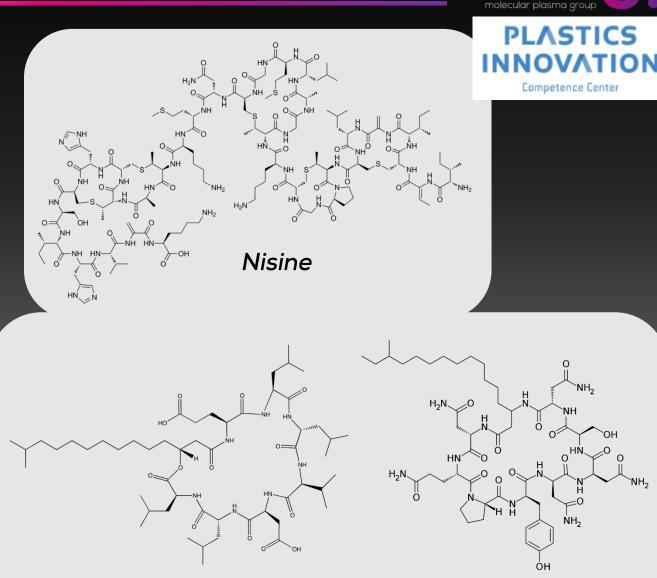
✓ tissue engineering

ANTIBACTERIAL COATINGS

Collaboration with PICC

Antimicrobial coatings using low temperature atmospheric plasma technology

Deposition of Nisine, Surfactine, Mycosubtiline



Mycosubtiline

Surfactine



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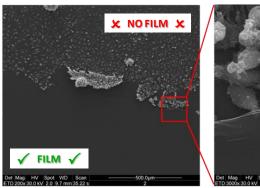
iRAP

Institute for

BIOMOLECULE DEPOSITION

BIOSENSORS, MICROFLUIDICS

ANTI-BIOFOULING COATINGS Protein- and cell-repellent surfaces

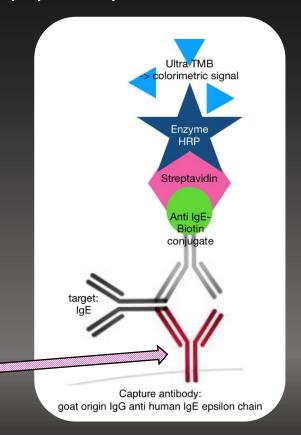


B. Nisol et al. Surf. Coat. Technol. 2014, 252, 126.

COMPLEX BIOMOLECULES

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Direct deposition of antibodies, peptides, proteins, DNA, ...

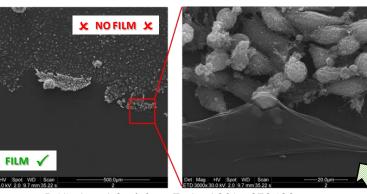


MEDICAL DEVICE Gold, Glass, C-Si wafer, Polymers (PMMA, PC, COC, PTFE...)

BIOMOLECULE DEPOSITION

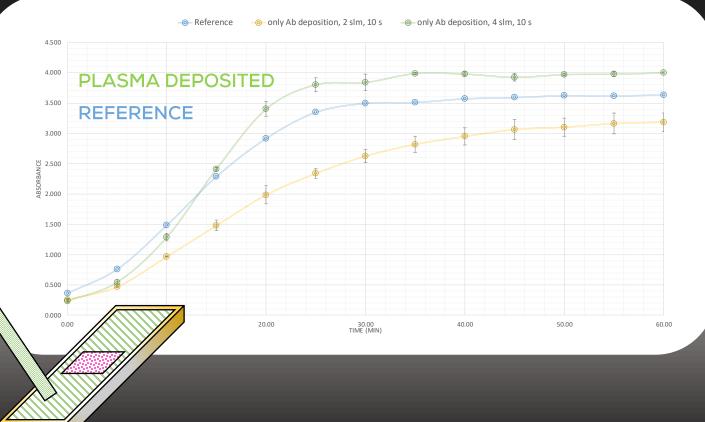
BIOSENSORS, MICROFLUIDICS

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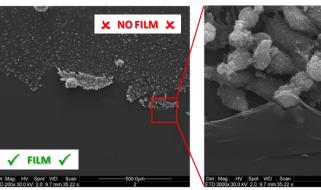
MEDICAL DEVICE Gold, Glass, C-Si wafer, Polymers (PMMA, PC, COC, PTFE...) COMPLEX BIOMOLECULES Direct deposition of antibodies, peptides, proteins, DNA, ... molecular plasma group



BIOMOLECULE DEPOSITION

BIOSENSORS, MICROFLUIDICS

ANTI-BIOFOULING COATINGS Protein- and cell-repellent surfaces



B. Nisol et al. Surf. Coat. Technol. 2014, 252, 126.

Gold, Glass, C-Si wafer, Polymers (PMMA, PC, COC, PTFE...)

MICROPATTERNING: SPECIFICALLY DESIGNED NOZZLE

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MEDICAL DEVICE



What type of molecules can graft on the surface?

There is no restriction on the type of organic chemistry •

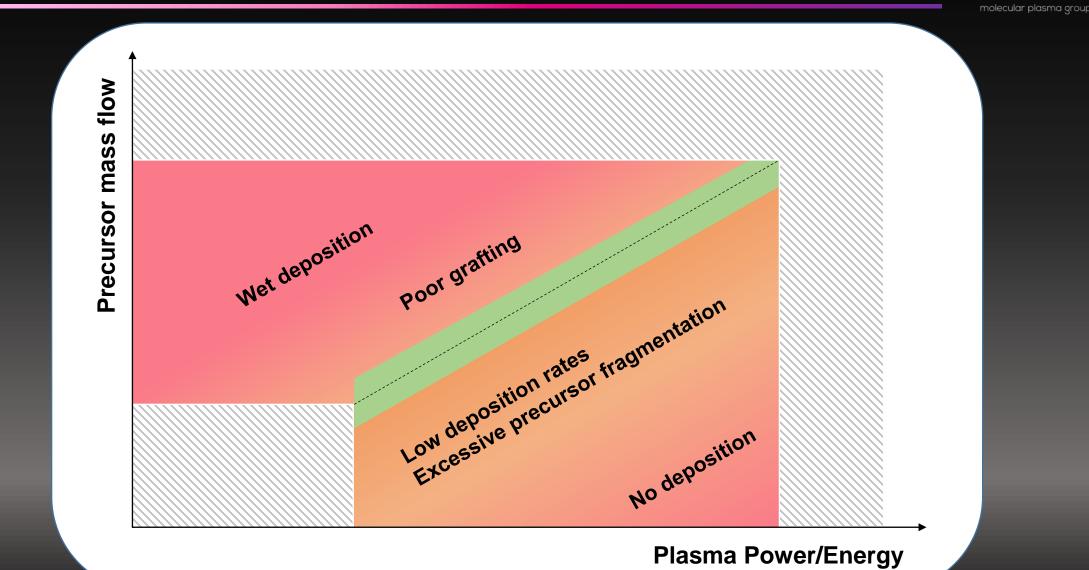
Pure liquids, mixtures, emulsions, suspensions of nanoparticles, or polymer solutions

Adhesion improvement \checkmark

- e.g. hydrophilic, reactive functional groups (amine, epoxy, acrylic, ...)
- Release coatings e.g. fluorinated & non-fluorinated molecules \checkmark
- **Biomolecule immobilization** \checkmark
- Anti-biofouling coatings e.g. \checkmark
- Virucidal coatings \checkmark
- Antimicrobial coatings \checkmark

- e.g. antibodies, peptides, proteins, DNA,...
- PEG-like, ...
- e.g. citric acid, ...
- e.g. antimicrobial peptides, quaternary ammonium

PLASMA COATING: ENERGY PER MOLECULE CONCEPT



- Hospital managers and Healthcare authorities can provide additional, well perceived virucidal protection with relatively small investment
- Also valid for other exposed professionals and general public

Contact MPG for access to manufacturers of certified virucidal masks



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