Development of antiseptic thin films by Remote Assisted Plasma Vacuum Deposition

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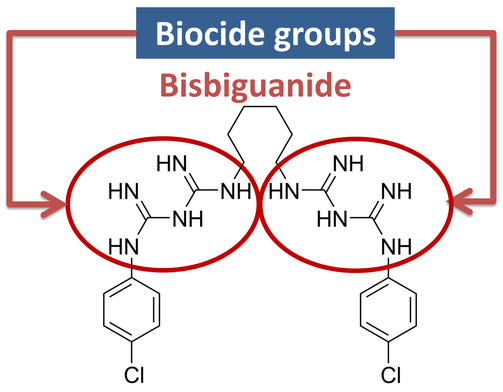
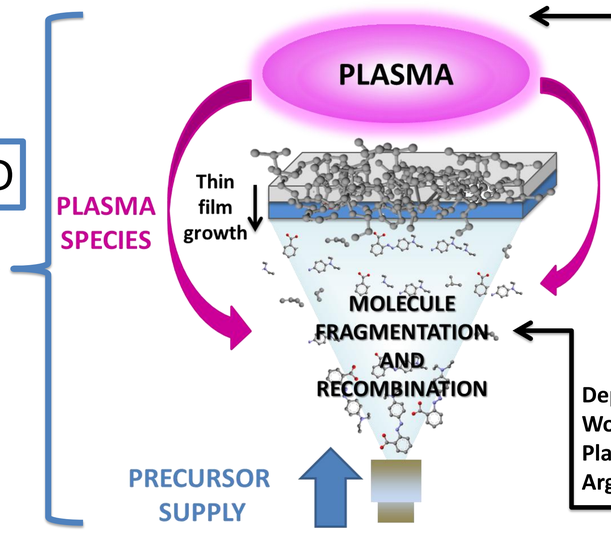
A novel family of **antiseptic biomaterials** is currently emerging up in order to prevent bacteria adherence and the **outbreak of infectious diseases** after surgery. The treatment of these infectious diseases is expensive and extremely complex in the majority of cases due to the current development of **antibiotic resistance strains**, what has forced the use of **broad-spectrum biocides** instead of traditional antibiotics [1]. In this context, we present the straightforward fabrication of **biocide nanometric coatings from a commercially available antiseptic, Chlorhexidine (CHX)**, by means of an innovative solvent-less process **named remote plasma assisted vacuum deposition (RPAVD).** The deposition is carried out at room temperature being compatible with the use of delicate and temperature-sensitive substrates (i.e., polymers and paper). This methodology provides a precise control over the degree of the interaction between plasma species and sublimated molecules. This enables the deposition of a highly crosslinked organic matrices with a **high retention of the chemical structure of the precursor molecules** [2].

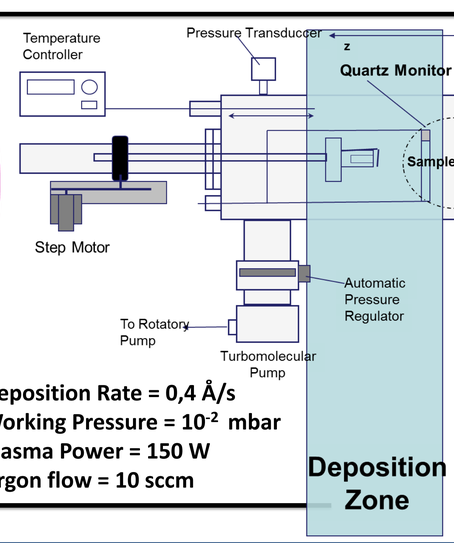
Precursor: Chlorhexidine

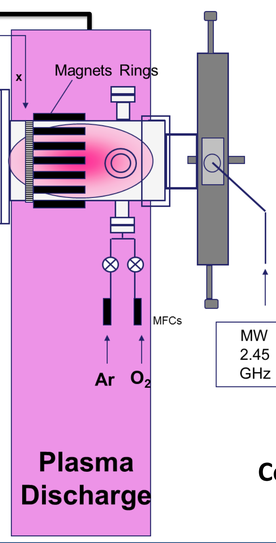


Structural formula of Chlorhexidine (CHX)

RPAVD



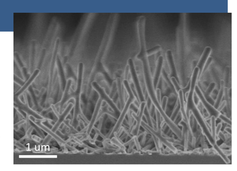




CHX is sublimated in the afterglow of a **microwave electron cyclotron resonance (MW-ECR)** reactor using **argon** as plasma gas.
CHX molecules interact with plasma species, taking place different recombination and fragmentation processes.

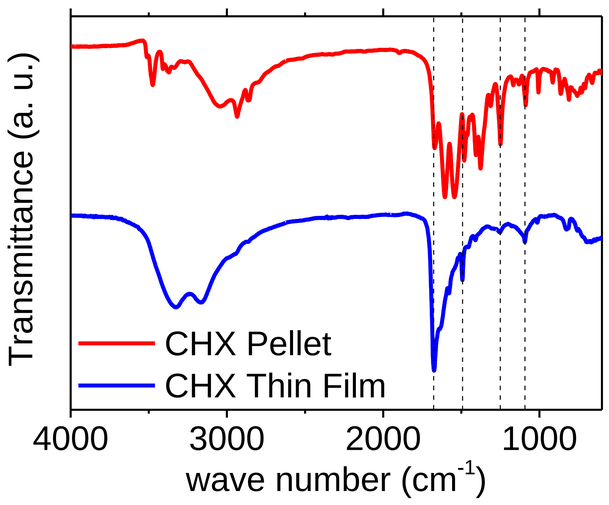
Different substrates have been used including **polydimethylsiloxane (PDMS)** pieces.

Conformal deposition is also possible



FT-IR Charaterization

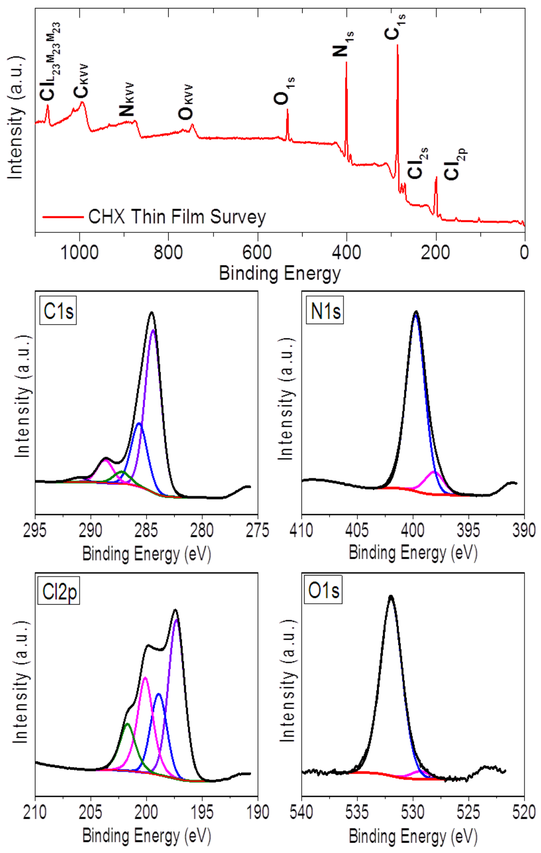
RPAVD thin film spectra dominated by an intense C=N feature → **Biguanide and/or guanidine** groups of reported antiseptic activity [3, 4].



Functional Group	Wave number (cm^{-1})
N-H/N=H Bisbiguanide	3050
C=N	1670
C=C	1492
δ (NH) + υ (C-N)	1375
C-N	1097
C-Cl	660
C-H aromatic ring	810

Retention of chemical functionalities of CHX responsible of the biocide character

XPS Characterization



Relative Atomic composition

Sample	N/C	Cl/C	O/C	Cl/N
CHX thin film	0,37	0,17	0,08	0,47
CHX molec	0,45	0,09	-	0,2

Presence of **chloride** and **nitrogenous** (imine and amine) groups at the surface

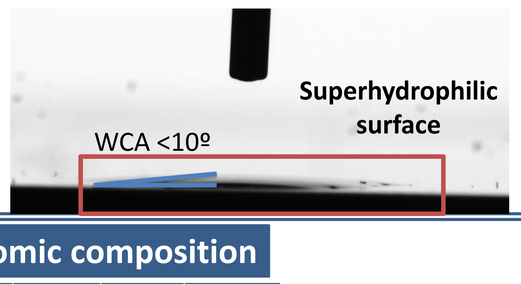
Wetting properties

Hydrophilicity is an essential requirement for **biocompatiblility** [5].

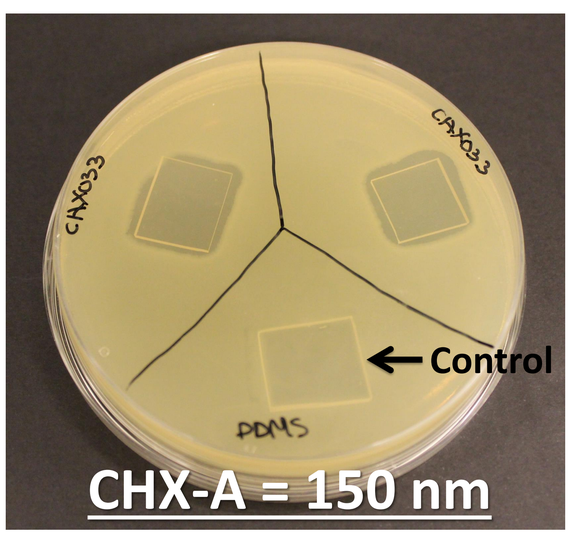
WCA<10º → **superhydrophilic surface**

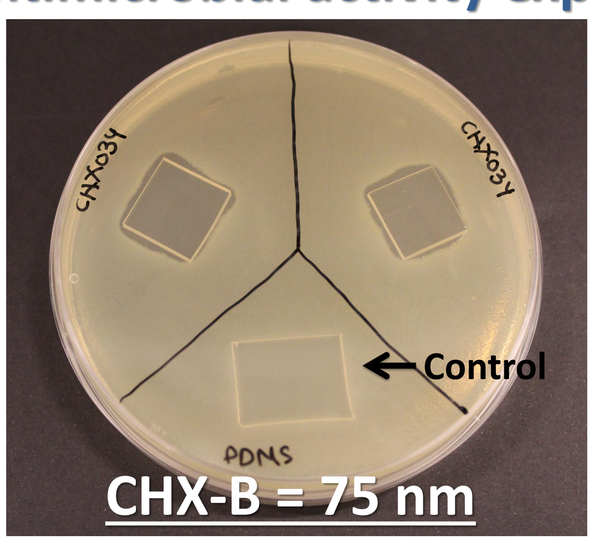
$$Surface\ energy: \gamma_S = \gamma^D + \gamma^P$$

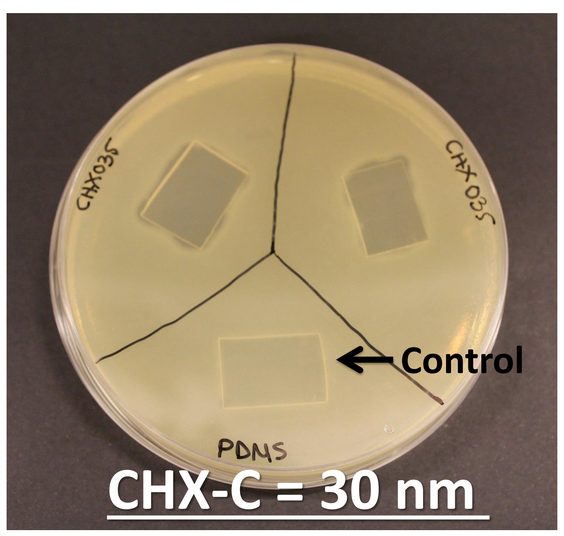
$$\gamma_S = 54{,}46 + 39{,}97 = \mathbf{98{,}43\ mJ/m^2}$$



Antimicrobial activity experiments







The antiseptic properties were studied by Agar diffusion method with ***E. Coli K12*** strain.

- **Bacteria growth was inhibited** in all the cases in the entire sample zone as compared to an uncoated PDMS foil used as negative control.
- The **radius of the inhibition** zone depends on the **thickness** of the thin films in the studied range (30-150 nm).

In conclusion**, biocide nanometric coatings** have been developed from a **commercial available antiseptic (CHX)** by an innovative synthesis mechanism never used before for this approach. The **biocide effect** of the developed coatings has been demonstrated directly over a **biomedical substrates**. The synthetic approach is clearly of potential interest for the **development of a novel family of antiseptic coatings.**

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References: [1] Bill G. X. Zhang et al Int. J. Mol. Sci. 15 (7), (2014) 11878-11921; [2] Francisco J. Aparicio et al. J. Mater. Chem. C, 2 (2014) 6561–6573, [3] P. Gilbert et al. Journal of Applied Microbiology 99 (2005) 703–715, [4] Aline Coqueiro et al. J. Nat. Prod., 77 (8) (2014) 1972–1975, [5] S. Bauer et al. Progress in Materials Science 58 (2013) 261–326.