

SURFACE MODIFICATION OF POLY(VINYL CHLORIDE) INTUBATION TUBES TO CONTROL BACTERIAL ADHESION : TEFLON-LIKE AND PLURONICS®

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INTRODUCTION: *Pseudomonas aeruginosa* is one of the most prevalent bacterial strains in a clinical environment, responsible for 30% of nosocomial pneumonia cases occurring in intubated and mechanically ventilated patients [1]. Colonization of the intubation device leads to mortality for over 40% of these cases, despite aggressive antibiotic therapy. Therefore, a strategy to reduce bacterial adhesion to intubation tubes is desirable. We are developing an approach based on the surface modification of the polymer used for this application, medical grade poly(vinyl chloride) (PVC). This paper investigates a method to prevent protein adsorption and eventual bacterial adhesion, as protein adhesion is believed to be a key event responsible for specific adhesion of bacteria to a surface.

The strategy is to mask the PVC substrate with a chemically inert Teflon-like fluoropolymer layer, which serves as an ideal platform for further surface modification due to its low surface energy properties[2]. By exploiting hydrophobic-hydrophobic interactions, we then bind protein and bacterial resistant[3,4] molecules, such as amphiphilic Pluronic®, to the fluoropolymer film.

METHODS:

This paper investigates fluoropolymer films created on PVC substrates through plasma-enhanced chemical vapor deposition. The films are deposited in a RF-plasma reactor, using C₂F₆ as a precursor and H₂ as a carrier gas. The PVC substrates were 1cm² sections cut from Mallinckrodt Medical Hi-Lo endotracheal tubes, which were flattened to allow the eventual microscopic counting of bacteria.

Further surface modification of the Teflon-like surfaces is completed through an incubation in Pluronic® (BASF) F108, a tri-block copolymer containing hydrophilic PEO and hydrophobic PPO chains.

Protein adhesion to the various surfaces is studied by incubating the samples in bovine serum albumin and fibrinogen, for a period of 3 h, at 37°C. The concentrations of albumin and fibrinogen used were 1 mg/ml, and 0.2 mg/ml, respectively.

XPS analysis of the various surfaces is performed using an imaging Kratos Axis Ultra (UK) X-ray

photoelectron spectrometer equipped with a hemispherical analyser. The X-ray source employed is a monochromatized Al K α .

Surface wettability is determined by contact angle measurements of deionized water sessile drops, using a microscope equipped with a goniometer (Krüss GmbH, Hamburg, Germany).

RESULTS: Teflon-like deposition on PVC yields a 21° increase in contact angle to a value of 104° for an 80% flow of C₂F₆ (Fig. 1). When C₂F₆ percentage is varied from 20% up to 80%, the contact angle increase is shown to be directly related to the quantity of CF_x groups incorporated in the film (data not shown), where 80% C₂F₆ shows the highest amount of fluorinated groups.

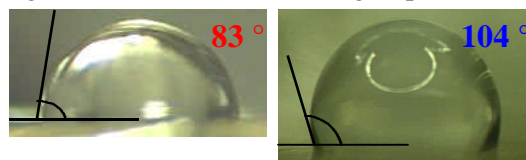


Fig. 1: Effect of Teflon-like deposition on surface wettability: native (left) and Teflon-like (right).

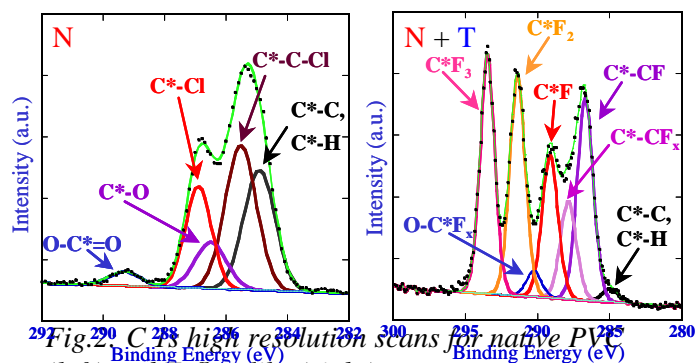


Fig. 2: C 1s high resolution scans for native PVC (left) and Teflon-like (right).

The C 1s high resolution scans of the Teflon-like films show that the native PVC is completely masked as there are no signatures, such as C-Cl, remaining (Fig. 2). Moreover, there is significant fluorocarbon group incorporation, including C-CF_x, C-F, C-F₂, C-F₃, which are all indicative of a Teflon-like layer. Pluronic® F108 does not adsorb to untreated native PVC. There is no change in contact angle for the native PVC following incubation with the F108 (Fig.3). Pluronic® F108 adsorption is achieved following Teflon-like

deposition on native PVC. Contact angle measurements confirm this as the contact angle of Teflon-like decreases by 14° following the F108 incubation (Fig.3). The O 1s high resolution scan of F108 incubates samples shows the incorporation of O-C groups, which are not present prior to incubation (data not shown).

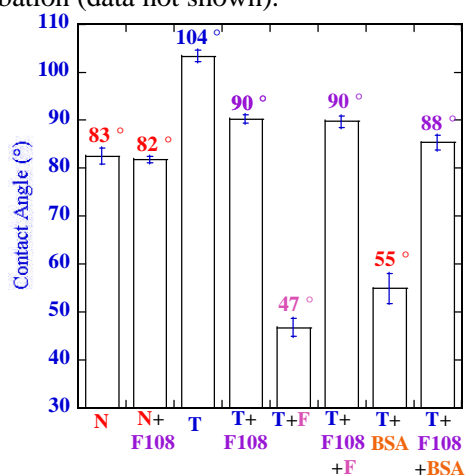


Fig.3: Contact angle evolution for native, Teflon-like and F108 modified samples. The graph also illustrates the evaluation of protein adhesion.

Pluronic® F108 incubation prevents fibrinogen adsorption to Teflon-like coated Native PVC. The T + F108 + Fibrinogen contact angle is identical to T + F108 (Fig.3), and nitrogenated functional groups representative of fibrinogen adsorption are absent on the O 1s high resolution scan following F108 modification. Pluronic® F108 also prevents albumin adsorption, as the contact angle follows the same trend as fibrinogen (Fig.3).

DISCUSSION & CONCLUSIONS: Teflon-like deposition on native PVC yields, a reproducible, hydrophobic surface modification, which serves as an excellent platform for further surface modification with Pluronic® F108. As shown by XPS analysis, the fluoropolymer completely masks the native surface, as no signatures of PVC are detectable following deposition. Contact angle measurements of the Teflon-like surfaces show that the PE-CVD techniques used yield a highly hydrophobic film (104°), where the contact angle achieved directly depends on the feed of C₂F₆ used during the deposition. Higher feeds of C₂F₆ allow for a greater incorporation of hydrophobic fluorocarbon groups in the film.

Pluronic® F108 does not adsorb to untreated native PVC, because the hydrophobic interactions are not strong enough to attract and bind the molecule. Pluronic® adsorption to PVC is only achieved following deposition of a Teflon-like film. XPS analysis shows evidence of F108 adsorption to Teflon-like surfaces through the detection of O-C functional groups, which are not present following

incubation of the molecule with native PVC. The reason for the adsorption to the Teflon-like film is the increased hydrophobicity, a 21° increase compared to native PVC surfaces. Contact angle measurements confirm the XPS data. Following Pluronic® F108 incubation with the Teflon-like samples there is a 14° decrease in contact angle, which indicates a surface modification. Following incubation with native PVC substrates, the contact angle remains unchanged.

Pluronic® F108 incubation is capable of preventing albumin and fibrinogen adsorption to Teflon-like coated PVC. Following incubation of fibrinogen and albumin to Teflon-like surfaces the contact angle drops from 104° to 47° and 55°, respectively. This decrease in contact angle indicates adsorption of proteins to the Teflon-like surface. This hypothesis is confirmed by XPS analysis, which detects nitrogenated functional groups characteristic of protein adsorption, such as O=C-N. However, following F108 modification of the Teflon-like surfaces, XPS analysis does not detect the functional groups indicative of protein adsorption. The O 1s high resolution spectra for the F108 modified samples which had been incubated in the protein solutions is identical to that of the F108 modified samples. Moreover, the contact angle of F108 modified surfaces following protein incubation, remains unchanged demonstrating the anti-fouling properties of the Pluronic® F108 molecules.

In conclusion, data from XPS analysis and contact angle measurements confirms that Pluronic® F108 modification of Teflon-like films is capable of producing surfaces resistant to protein adhesion. As protein adhesion is believed to be the triggering event in the inflammatory response and eventual failure of biomaterials, this method could prove to be useful in creating anti-fouling surfaces.

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